41st Congress, 3d Session. | HOUSE OF REPRESENTATIVES. | Ex. Doc. No. 153.

ANNUAL REPORT

OF

THE BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION,

SHOWING

THE OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION FOR THE YEAR 1869.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1871.

387108

CONGRESS OF THE UNITED STATES, IN THE HOUSE OF REPRESENTATIVES,
FORTY-FIRST CONGRESS, SECOND SESSION, *July* 12, 1870.

Resolved by the House of Representatives, (*the Senate concurring*,) That ten thousand additional copies of the Report of the Smithsonian Institution for the year 1869 be printed, three thousand of which shall be for the use of the Senate, four thousand for the use of the House, and three thousand for the use of the Institution: *Provided*, That the aggregate number of pages of said report shall not exceed four hundred and fifty, and that there shall be no illustrations except those furnished by the Smithsonian Institution.

On the 13th of July, 1870, a message was received from the Senate, by Mr. Gorham, its Secretary, notifying the House that the Senate had agreed to the said resolution without amendment.

Attest: EDW. McPHERSON, *Clerk.*
Per GEO. FRS. DAWSON, *Assistant Clerk.*

LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

TRANSMITTING

The annual report of the Smithsonian Institution for the year 1869.

SMITHSONIAN INSTITUTION,
Washington, March 1, 1870.

SIR: In behalf of the Board of Regents, I have the honor to submit to the Congress of the United States the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year 1869.

I have the honor to be, very respectfully, your obedient servant,

JOSEPH HENRY,
Secretary Smithsonian Institution.

Hon. S. COLFAX,
President of the Senate.

Hon. J. G. BLAINE,
Speaker of the House of Representatives.

ANNUAL REPORT OF THE SMITHSONIAN INSTITUTION FOR 1869.

This document contains: 1. The programme of organization of the Smithsonian Institution. 2. The annual report of the secretary, giving an account of the operations and condition of the establishment for the year 1869, with the statistics of collections, exchanges, meteorology, &c. 3. The report of the executive committee, exhibiting the financial affairs of the Institution, including a statement of the Smithson fund, the receipts and expenditures for the year 1869, and the estimates for 1870. 4. The proceedings of the Board of Regents. 5. A general appendix, consisting principally of reports of lectures, translations from foreing journals of articles not generally accessible, but of interest to meteorologists, correspondents of the Institution, teachers, and others interested in the promotion of knowledge.

THE SMITHSONIAN INSTITUTION.

ULYSSES S. GRANT.....President of the United States, *ex officio* Presiding Officer of the Institution.
SALMON P. CHASE.....Chief Justice of the United States, Chancellor of the Institution, President of the Board of Regents.
JOSEPH HENRY........Secretary (or Director) of the Institution.

REGENTS OF THE INSTITUTION.

S. P. CHASE ....Chief Justice of the United States, *President of the Board*

S. COLFAX..................Vice-President of the United States.
S. J. BOWEN...............Mayor of the City of Washington.
L. TRUMBULL ....Member of the Senate of the United States.
GARRETT DAVIS ....Member of the Senate of the United States.
H. HAMLIN ....Member of the Senate of the United States.
J. A. GARFIELD ....Member of the House of Representatives.
L. P. POLAND ....Member of the House of Representatives.
S. S. COX ....Member of the House of Representatives.
W. B. ASTOR ....Citizen of New York.
T. D. WOOLSEY ....Citizen of Connecticut.
L. AGASSIZ ....Citizen of Massachusetts.

RICHARD DELAFIELD...Citizen of Washington.
PETER PARKER ....Citizen of Washington.
JOHN MACLEAN ....Citizen of New Jersey.

(Richard Delafield, Peter Parker, John Maclean: EXECUTIVE COMMITTEE.)

MEMBERS EX OFFICIO OF THE INSTITUTION.

U. S. GRANT.............President of the United States.
S. COLFAX ....Vice-President of the United States.
S. P. CHASE...............Chief Justice of the United States.
H. FISH ....Secretary of State.
G. S. BOUTWELL.........Secretary of the Treasury.
W. W. BELKNAP ....Secretary of War.
G. M. ROBESON...........Secretary of the Navy.
J. A. J. CRESWELL.......Postmaster General.
J. D. COX...................Secretary of the Interior.
E. R. HOAR ....Attorney General.
S. S. FISHER ....Commissioner of Patents.
S. J. BOWEN...............Mayor of the City of Washington.

EXECUTIVE OFFICERS OF THE INSTITUTION.

JOSEPH HENRY, SECRETARY,

Director of the Institution.

SPENCER F. BAIRD, ASSISTANT SECRETARY,

In charge of Museum, Exchanges, &c.

WILLIAM J. RHEES, CHIEF CLERK,

In charge of Accounts, Printing, and General Business.

DANIEL LEECH, CLERK,

In charge of Correspondence.

HENRY M. BANNISTER, CLERK,

In charge of Meteorology.

JANE A. TURNER, CLERK,

In charge of Records of International Exchanges.

SOLOMON G. BROWN, CLERK,

In charge of Transportation.

JOSEPH HERRON,

Janitor of the Museum.

PROGRAMME OF ORGANIZATION

OF THE

SMITHSONIAN INSTITUTION.

[PRESENTED IN THE FIRST ANNUAL REPORT OF THE SECRETARY, AND ADOPTED BY THE BOARD OF REGENTS, DECEMBER 13, 1847.]

INTRODUCTION.

General considerations which should serve as a guide in adopting a Plan of Organization.

1. WILL OF SMITHSON. The property is bequeathed to the United States of America, "to found at Washington, under the name of the SMITHSONIAN INSTITUTION, an establishment for the increase and diffusion of knowledge among men."

2. The bequest is for the benefit of mankind. The Government of the United States is merely a trustee to carry out the design of the testator.

3. The Institution is not a national establishment, as is frequently supposed, but the establishment of an individual, and is to bear and perpetuate his name.

4. The objects of the Institution are, 1st, to increase, and, 2d, to diffuse knowledge among men.

5. These two objects should not be confounded with one another. The first is to enlarge the existing stock of knowledge by the addition of new truths; and the second, to disseminate knowledge, thus increased, among men.

6. The will makes no restriction in favor of any particular kind of knowledge; hence all branches are entitled to a share of attention.

7. Knowledge can be increased by different methods of facilitating and promoting the discovery of new truths; and can be most extensively diffused among men by means of the press.

8. To effect the greatest amount of good, the organization should be such as to enable the Institution to produce results, in the way of increasing and diffusing knowledge, which cannot be produced either at all or so efficiently by the existing institutions in our country.

9. The organization should also be such as can be adopted provisionally; can be easily reduced to practice; receive modifications, or be abandoned, in whole or in part, without a sacrifice of the funds.

10. In order to compensate in some measure for the loss of time occasioned by the delay of eight years in establishing the Institution, a considerable portion of the interest which has accrued should be added to the principal.

11. In proportion to the wide field of knowledge to be cultivated, the funds are small. Economy should, therefore, be consulted in the construction of the building; and not only the first cost of the edifice should be considered, but also the continual expense of keeping it in repair,

and of the support of the establishment necessarily connected with it. There should also be but few individuals permanently supported by the Institution.

12. The plan and dimensions of the building should be determined by the plan of the organization, and not the converse.

13. It should be recollected that mankind in general are to be benefited by the bequest, and that, therefore, all unnecessary expenditure on local objects would be a perversion of the trust.

14. Besides the foregoing considerations, deduced immediately from the will of Smithson, regard must be had to certain requirements of the act of Congress establishing the Institution. These are, a library, a museum, and a gallery of art, with a building on a liberal scale to contain them.

SECTION I.

Plan of organization of the Institution in accordance with the foregoing deductions from the will of Smithson.

To INCREASE KNOWLEDGE. It is proposed—

1. To stimulate men of talent to make original researches, by offering suitable rewards for memoirs containing new truths; and,

2. To appropriate annually a portion of the income for particular researches, under the direction of suitable persons.

To DIFFUSE KNOWLEDGE. It is proposed—

1. To publish a series of periodical reports on the progress of the different branches of knowledge; and,

2. To publish occasionally separate treatises on subjects of general interest.

DETAILS OF THE PLAN TO INCREASE KNOWLEDGE.

I. *By stimulating researches.*

1. Facilities afforded for the production of original memoirs on all branches of knowledge.

2. The memoirs thus obtained to be published in a series of volumes, in a quarto form, and entitled Smithsonian Contributions to Knowledge.

3. No memoir on subjects of physical science to be accepted for publication which does not furnish a positive addition to human knowledge, resting on original research; and all unverified speculations to be rejected.

4. Each memoir presented to the Institution to be submitted for examination to a commission of persons of reputation for learning in the branch to which the memoir pertains; and to be accepted for publication only in case the report of this commission is favorable.

5. The commission to be chosen by the officers of the Institution, and the name of the author, as far as practicable, concealed, unless a favorable decision is made.

6. The volumes of the memoirs to be exchanged for the transactions of literary and scientific societies, and copies to be given to all the colleges and principal libraries in this country. One part of the remaining copies may be offered for sale, and the other carefully preserved, to form complete sets of the work, to supply the demand from new institutions.

7. An abstract, or popular account, of the contents of these memoirs

to be given to the public through the annual report of the Regents to Congress.

II. *By appropriating a part of the income, annually, to special objects of research, under the direction of suitable persons.*

1. The objects and the amount appropriated, to be recommended by counsellors of the Institution.

2. Appropriations in different years to different objects; so that in course of time each branch of knowledge may receive a share.

3. The results obtained from these appropriations to be published, with the memoirs before mentioned, in the volumes of the Smithsonian Contributions to Knowledge.

4. Examples of objects for which appropriations may be made.

(1.) System of extended meteorological observations for solving the problem of American storms.

(2.) Explorations in descriptive natural history, and geological, magnetical, and topographical surveys, to collect materials for the formation of a Physical Atlas of the United States.

(3.) Solution of experimental problems, such as a new determination of the weight of the earth, of the velocity of electricity, and of light; chemical analyses of soils and plants; collection and publication of scientific facts accumulated in the offices of government.

(4.) Institution of statistical inquiries with reference to physical, moral, and political subjects.

(5.) Historical researches, and accurate surveys of places celebrated in American history.

(6.) Ethnological researches, particularly with reference to the different races of men in North America; also, explorations and accurate surveys of the mounds and other remains of the ancient people of our country.

DETAILS OF THE PLAN FOR DIFFUSING KNOWLEDGE.

I. *By the publication of a series of reports, giving an account of the new discoveries in science, and of the changes made from year to year in all branches of knowledge not strictly professional.*

1. These reports will diffuse a kind of knowledge generally interesting, but which, at present, is inaccessible to the public. Some of the reports may be published annually, others at longer intervals, as the income of the Institution or the changes in the branches of knowledge may indicate.

2. The reports are to be prepared by collaborators eminent in the different branches of knowledge.

3. Each collaborator to be furnished with the journals and publications, domestic and foreign, necessary to the compilation of his report; to be paid a certain sum for his labors, and to be named on the title-page of the report.

4. The reports to be published in separate parts, so that persons interested in a particular branch can procure the parts relating to it without purchasing the whole.

5. These reports may be presented to Congress, for partial distribution, the remaining copies to be given to literary and scientific institutions, and sold to individuals for a moderate price.

The following are some of the subjects which may be embraced in the reports:*

* This part of the plan has been but partially carried out.

I. PHYSICAL CLASS.

1. Physics, including astronomy, natural philosophy, chemistry, and meteorology.
2. Natural history, including botany, zoölogy, geology, &c.
3. Agriculture.
4. Application of science to arts.

II. MORAL AND POLITICAL CLASS.

5. Ethnology, including particular history, comparative philology, antiquities, &c.
6. Statistics and political economy.
7. Mental and moral philosophy.
8. A survey of the political events of the world; penal reform, &c.

III. LITERATURE AND THE FINE ARTS.

9. Modern literature.
10. The fine arts, and their application to the useful arts.
11. Bibliography.
12. Obituary notices of distinguished individuals.

II. *By the publication of separate treatises on subjects of general interest.*

1. These treatises may occasionally consist of valuable memoirs translated from foreign languages, or of articles prepared under the direction of the Institution, or procured by offering premiums for the best exposition of a given subject.

2. The treatises should, in all cases, be submitted to a commission of competent judges, previous to their publication.

3. As examples of these treatises, expositions may be obtained of the present state of the several branches of knowledge mentioned in the table of reports.

SECTION II.

Plan of organization, in accordance with the terms of the resolutions of the Board of Regents providing for the two modes of increasing and diffusing knowledge.

1. The act of Congress establishing the Institution contemplated the formation of a library and a museum; and the Board of Regents, including these objects in the plan of organization, resolved to divide the income* into two equal parts.

2. One part to be appropriated to increase and diffuse knowledge by means of publications and researches, agreeably to the scheme before given. The other part to be appropriated to the formation of a library and a collection of objects of nature and of art.

3. These two plans are not incompatible with one another.

4. To carry out the plan before described, a library will be required, consisting, 1st, of a complete collection of the transactions and proceedings of all the learned societies in the world; 2d, of the more important current periodical publications, and other works necessary in preparing the periodical reports.

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* The amount of the Smithsonian bequest received into the Treasury of the United States is	$515,169 00
Interest on the same to July 1, 1846, (devoted to the erection of the building)	242,129 00
Annual income from the bequest	30,910 14

5. The Institution should make special collections, particularly of objects to illustrate and verify its own publications.

6. Also, a collection of instruments of research in all branches of experimental science.

7. With reference to the collection of books, other than those mentioned above, catalogues of all the different libraries in the United States should be procured, in order that the valuable books first purchased may be such as are not to be found in the United States.

8. Also, catalogues of memoirs, and of books and other materials, should be collected for rendering the Institution a center of bibliographical knowledge, whence the student may be directed to any work which he may require.

9. It is believed that the collections in natural history will increase by donation as rapidly as the income of the Institution can make provision for their reception, and, therefore, it will seldom be necessary to purchase articles of this kind.

10. Attempts should be made to procure for the gallery of art casts of the most celebrated articles of ancient and modern sculpture.

11. The arts may be encouraged by providing a room, free of expense, for the exhibition of the objects of the Art-Union and other similar societies.

12. A small appropriation should annually be made for models of antiquities, such as those of the remains of ancient temples, &c.

13. For the present, or until the building is fully completed, besides the Secretary, no permanent assistant will be required, except one, to act as librarian.

14. The Secretary, by the law of Congress, is alone responsible to the Regents. He shall take charge of the building and property, keep a record of proceedings, discharge the duties of librarian and keeper of the museum, and may, with the consent of the Regents, *employ assistants.*

15. The Secretary and his assistants, during the session of Congress, will be required to illustrate new discoveries in science, and to exhibit new objects of art. Distinguished individuals should also be invited to give lectures on subjects of general interest.

This programme, which was at first adopted provisionally, has become the settled policy of the Institution. The only material change is that expressed by the following resolutions, adopted January 15, 1855, viz:

Resolved, That the 7th resolution passed by the Board of Regents, on the 26th of January, 1847, requiring an equal division of the income between the active operations and the museum and library, when the buildings are completed, be, and it is hereby, repealed.

Resolved, That hereafter the annual appropriations shall be apportioned specifically among the different objects and operations of the Institution, in such manner as may, in the judgment of the Regents, be necessary and proper for each, according to its intrinsic importance and a compliance in good faith with the law.

REPORT

OF

PROFESSOR HENRY, SECRETARY OF THE SMITHSONIAN INSTITUTION,

FOR

1869.

To the Board of Regents:

GENTLEMEN: The Institution intrusted to your guardianship by the Congress of the United States, has, during the past year, continued its operations in the line of increasing and diffusing knowledge with unabated energy. The sphere of its influence in this country and abroad has from the first been constantly on the increase, and it is now not too much to say that no institution founded by the liberality of a private individual ever attained a wider or more favorable reputation. It is true, its character is sometimes misunderstood, but this cannot be a matter of surprise when we reflect that it differs in many particulars from all other institutions, and that without an attentive perusal of the annual reports, no adequate idea can be obtained of its varied field of labor, or of what it has done and is doing to promote the special objects denoted in the will of its founder. It is here sufficient to mention that, besides adding to the sum of human knowledge by its own operations, and connecting its name with the history of almost every branch of science, it has become the general agent through which the intellectual labors of the eastern and western hemispheres are brought into efficient coöperation. The importance of its labors and the influence of the international communication which it has established, can only be properly estimated by those who are acquainted with the distinctive characteristics of modern civilization, and who realize the fact that it mainly rests on the development of a knowledge of the laws of nature and the application of these laws to the uses of life. Science not only gives man control over the physical elements, and thus tends to emancipate him from the curse of brute labor, but also serves to widen the domain of his intellectual activities and enlarge the sphere of his moral sympathies. By an attentive perusal of the following report, I think it will be admitted by all who are competent to form a proper opinion on the subject, that what I have claimed for the Institution is not too much, and that any departure from the general policy which has been constantly pursued from the beginning, would be attended with unfortunate consequences.

FINANCES.—At the last session of the Board it was resolved that a memorial be presented to Congress, setting forth the large expendi-

ture to which the Institution had been subjected by reason of the accommodation and maintenance of the National Museum, and asking that the usual appropriation of $4,000 that had been made on this account be increased to $10,000; also, that $25,000 be appropriated toward fitting up the large room in the second story of the main building, for the better exhibition of the government collections. In accordance with this resolution a petition was prepared, signed by the Chancellor and Secretary of the Institution, and presented to the House of Representatives by General Garfield, one of the Regents. It was referred to the Committee on Appropriations, and although forcibly advocated by the members of the Board belonging to the House, it was not granted, and only the usual sum was appropriated. The same memorial has, through the Secretary of the Interior, again been presented to Congress. The reasonableness of this petition must be manifest when it is considered that $4,000 is the sum which the maintenance of the museum cost the government when it was in charge of the Patent Office, and that since its removal to the Institution it has increased to three times its original size, while the money has depreciated to one-half its former value. From an accurate analysis of the accounts it appears that the items directly chargeable to the museum during the past year amount to $15,000. This sum is exclusive of the interest on $144,000, which has been expended since the fire in the restoration of the building, principally for the accommodations for the museum. Owing to the fall in the premium on gold, and the non-payment of interest by the State of Virginia on bonds held by the Institution, the income during the past year has been less than the estimate by upward of $2,400. It has, therefore, been necessary to diminish expenditures in certain directions, in order to carry out the plan of accumulating a sufficient surplus in the treasury at the beginning of the year to defray, in cash, as far as possible, all the current expenses. From the report of the Executive Committee it will be seen that this plan has been rigorously carried out; that the balance on hand at the beginning of 1870 was nearly $21,000, with outstanding bills of $3,000, which is about the amount of indebtedness at the commencement of last year. The finances of the Institution may, therefore, be exhibited as follows:

The whole bequest of Smithson in the United States Treasury	$541,379 63
Additions from savings, &c., also in the United States Treasury	108,620 37
Virginia State stock, ($72,760,) valued at	42,200 80
Cash on hand	20,969 65
Total	713,170 45
Deduct bills due, (about)	2,969 65
Which leaves, as the present capital	710,200 80

The income from the Smithson fund during the year 1869, including the premium on gold, was $49,515.

In a late report from the Treasury Department, giving a list of the appropriations of Congress for the District of Columbia, a large amount is put down to the Smithsonian Institution. This statement, without explanation, would give an erroneous impression. From the organization of the Institution to the present time it cannot properly be said that the government has appropriated a single dollar from the public treasury for the Institution. The principal "appropriations" mentioned in the report in question were not from the public money, but from the Smithson fund deposited in the Treasury of the United States. The only appropriation from the national treasury which might appear to be for the benefit of the Institution, is that of $4,000, annually made for the care and exhibition of the Government Museum, and, also, at one time $10,000, and at another $4,000, to erect cases for the better preservation of the specimens; and even in these instances, as has been shown, the Institution was far from being reimbursed for the actual expenditure on the care of the museum.

Coöperation with Government Departments.—It has always been a prominent feature in the policy of the Institution to act in unison with other institutions, and especially to coöperate with the several departments and bureaus of the general government in all cases in which their respective functions would admit of such coöperation. It is in accordance with this policy that the extensive and rapidly increasing library of the Institution has been incorporated with that of Congress, and that a similar arrangement, mentioned in the last report, for transferring to the Department of Agriculture the large Smithsonian herbarium, has been completed. It is also in accordance with this policy that an arrangement has been made with Surgeon General Barnes by which all the crania and other of the osteological specimens of the Institution have been transferred to the Army Medical Museum.

These coöperations, while they relieve the Institution from the expenditure of more than $10,000 annually, and thus enable it to more vigorously prosecute its researches, to publish a larger number of contributions, and to extend its system of international exchanges, tend also to increase the amount of scientific material in the capital of the United States, as well as to facilitate its employment in the advance and diffusion of knowledge.

This Institution and its collaborators have the use not only of its books deposited in the Capitol, but also that of those in the National Library, as may be seen by the terms of the deposit given in a previous report. Also, agreeably to the terms upon which the plants were transferred, they are accessible to the public for practical or educational purposes, and to the Institution for scientific investigation. Furthermore, a botanist approved by the Institution has been appointed, who

is to have charge of the specimens and be ready at all times to give botanical information that may be required by the general public or by the Smithsonian correspondents. Moreover, in return for the specimens transferred to the Medical Museum the Institution receives from the officers of the army all collections made in ethnology and in special branches of natural history.

PUBLICATIONS.—The publications of the Institution form an essential part of its operations and constitute the principal basis of the great system of Smithsonian international exchanges. As has been frequently stated in previous reports, they are of three classes: the Contributions to Knowledge, the Miscellaneous Collections, and the Annual Reports. The first consist of memoirs containing positive additions to science resting on original research, and which are, principally, the result of investigations to which the Institution has in some way rendered assistance. The Miscellaneous Collections are chiefly composed of works intended to facilitate the study of ethnology, natural history, and meteorology. They are designed to facilitate the progress of those who engage in special studies, to which, in their leisure moments, their thoughts may recur, and in connection with which, while contributing to their own pleasure, they may advance the cause of science. The Annual Reports, besides giving an account of the operations of the Institution, furnish, in an appendix, matter of importance to the meteorological observer and of interest to the general public. The Contributions and Miscellaneous Collections are published at the expense of the Smithson fund, while the Reports, with the exception of the illustrations, are printed by the government.

The following is a list of the quarto publications that have been printed during the present year:

1. On the Gray Substance of the Medulla Oblongata and Trapezium. By John Dean, M. D.

2. On the Orbit and Phenomena of a Meteoric Fire-ball, seen July 20, 1860. By Professor J. H. Coffin, LL.D.

3. On the Transatlantic Longitude. By Benjamin A. Gould.

4. The Indians of Cape Flattery, at the Entrance of the Strait of Fuca, Washington Territory. By J. G. Swan.

5. Systems of Consanguinity and Affinity of the Human Family. By Lewis H. Morgan.

6. On the Gliddon Mummy Case in the Museum of the Smithsonian Institution. By Chas. Pickering.

7. A new edition of Brewer's North American Oölogy.

Of these Nos. 1 to 6, together with Hildreth's and Cleveland's Meteorological Observations, previously described, form the 16th volume of Smithsonian Contributions to Knowledge, which will be distributed to the foreign correspondents of the Institution in the next invoice, and, as soon as an additional number can be bound, to the public institutions of this country.

The following are the titles of the articles of the octavo series that have been printed during the year, or are now in press:

1. Land and Fresh Water Shells of North America. Part I. By W. G. Binney and T. Bland.

2. Photographic Portraits of North American Indians in the Gallery of the Smithsonian Institution.

3. List of Foreign Correspondents of the Smithsonian Institution. New and enlarged edition.

4. Directions for Collecting, Preserving and Transporting Specimens of Natural History. Prepared for the use of the Smithsonian Institution. (New edition.)

5. Tables, Meteorological and Physical, prepared for the Smithsonian Institution. By A. Guyot, P. D., LL. D. (New edition.)

6. Circular in Reference to the Degrees of Relationship among Different Nations. (New edition.)

At the request of the Institution the preparation of the Manual of the Land and Fresh Water Shells of North America was undertaken by W. G. Binney. The second and third parts of this work were published some years ago, and have been described in previous reports. The first part, which completes the work, was issued during the year 1869, and forms by itself a volume of 328 pages, illustrated with many woodcuts. The work was at first undertaken by Mr. Binney alone, but he afterward, in this part, associated with himself Mr. Thomas Bland, of New York. It contains a description of all the species of land shells known in January 1868, within the geographical limits of North America, from the extreme North to the Rio Grande and Mazatlan. It is considered a valuable contribution to the study of conchology and is in great demand among those interested in the pursuit of this branch of natural history.

From the stereotype plates of these octavo works, from which impressions have been printed and separately distributed in pamphlet form, two additional volumes of the Miscellaneous Collections have been made up, and are nearly ready for distribution.

On account of the great outlay for the building during the last few years, the appropriations for publications have been restricted; yet from the foregoing it will be seen that we shall be able to distribute in our next foreign invoice one quarto and two octavo volumes, which, with the Annual Report, will make four volumes of publications issued during 1869.

A brief account has been given in previous reports of the contents of all the papers forming the 16th volume of Contributions, excepting the Gliddon Mummy Case, the Indians of Cape Flattery, and the Transatlantic Longitude.

The first of these is by Dr. Charles Pickering, of Boston, one of the ethnologists of the United States Exploring Expedition, under Admiral Wilkes. It relates to an interesting specimen of Egyptian archæology

presented, in 1842, by Mr. Gliddon, the Egyptologist, to the national collection now in charge of the Smithsonian Institution, but at that time in the United States Patent Office. It consists of a part of the lid of a mummy case procured at Sacara from an Arab. It does not bear any inscription by which its date can be determined, but it is supposed by Dr. Pickering to belong to a very early period, and to be among the oldest—if not the very oldest—of specimens of hieroglyphic writing known. The earliest writing, of ascertained date, was executed in the third dynasty from 3110 to 3080, B. C.; but, according to Dr. Pickering, the writings on the mummy case in the Institution are of a style different from, and clearly anterior to, that executed in the third dynasty. Toward the beginning of this era, on the authority of Manetho, writing was improved, and as all improvements of this kind have tended in the direction of an increased facility, this mummy case at least seems to have preceded such a change. The lid was divided by Mr. Gliddon into three parts; the first part is the one just described, the second was presented to the Naval Lyceum of Brooklyn, the third to Mrs. Ward, of New York. Diligent though unsuccessful inquiry has been made for the missing parts, in order to have them also figured and described; and now, through this report, attention is again called to the subject, with the hope that if the other portions of the lid are still in existence, information of the fact may be communicated to the Institution. The part of the lid above described is represented on a large plate which presents a fac-simile of the figures as to size and color.

The second undescribed paper is that on the Indians of Cape Flattery, which, there is no doubt, will be considered an interesting contribution to ethnology. It was prepared, at the request of the Institution, by Mr. James G. Swan, an agent of the United States government, who had long resided with the tribe of which he has given an account. This tribe occupies the extreme northwestern part of Washington Territory, opposite Vancouver's Island, from which it is separated by the Strait of Fuca. The paper contains a full account of the manners and customs of these Indians, and a description of their implements, utensils, clothing, modes of travel, fashion of constructing houses, &c. It also gives a minute account of the festivals and ceremonies of these Indians, and of the various myths with which these are connected. Among other singular superstitions is that of the resurrection, as it were, of the flesh of the body but not of the bones, which are left in the graves; that the spirit world is in the center of the earth, where the inhabitants are somewhat incommoded by the want of the osseous part of their bodies. The memoir is illustrated by a large number of woodcuts, most of them copied from specimens now in the museum of the Institution. In the absence of the author of the work it was edited by George Gibbs, esq., who has added occasional notes, and also a vocabulary of the Makah tribe, furnished by Mr. Swan.

The third memoir to be described is the report of Dr. B. A. Gould on

the Transatlantic Longitude. The principal results of this investigation were communicated by Dr. Gould to the meeting of the National Academy of Sciences, during its session in 1867, and the report in full was presented to the Institution for publication, with the consent of the Superintendent of the Coast Survey, Professor Peirce, in February 1869. It relates to the determination of the difference of longitude between England and America, by means of the electro-magnetic telegraph. This method was first practically applied in the Coast Survey of the United States, between places in this country, and received its full development in this great national work before it began to be used elsewhere. Previous to the introduction of this method, three others had been employed on the Survey. First, that of observations of the time of the culmination of the moon at the two places between which the difference of longitude, or, in other words, of time, was to be determined; second, that of observing the times of beginning and ending of eclipses of the sun and of occultations of known stars by the passage over them of the moon; and third, that of transporting a large number of chronometers between England and America a number of times in succession and obtaining the average difference of time as indicated by the whole series. The determinations of the transatlantic longitude which have been obtained by these methods have been generally referred to the Capitol at Washington and the Observatory at Greenwich, England, as standard points. From the several methods just mentioned, and also from that of the electro-magnetic telegraph, the following results have been obtained:

From eclipses and occultations the difference in time between the dome of the Capitol and the Greenwich Observatory is	5^h	8^m	$14^s.86$
From moon culminations the difference is	5^h	8^m	$10^s.12$
From the transportation of chronometers the difference is	5^h	8^m	$12^s.30$
From the transmission of electricity through the cable, and the use of the electro-magnetic telegraph, the difference was found to be	5^h	8^m	$12^s.45$

By the last method the difference of time between the ends of the cable was probably determined within the fraction of a second, but as the signals could not be sent directly between Greenwich and Washington, a somewhat greater departure from the actual difference must be allowed. This difference is, however, very small, not exceeding, perhaps, a single second.

The process of ascertaining the difference of time, or in other words, the difference of longitude of two points, by means of the telegraph, consists in transmitting a series of signals either way through the conductor, and in observing the exact time of the appearance of the signal at one station, while its time of starting is registered at the other. If

the transmission of the signal were instantaneous, the difference of time observed would be the exact difference of longitude; but if any time elapses between the making of the signal at one station and its appearance at the other, the difference of time will be greater than the true time when the signal is sent eastward, and less than it when sent westward. If the velocity of transmission be the same in both directions, the true difference of longitude will be obtained by taking the mean of two sets of differences, the one giving the longitude as much too great as the other gives it too small.

From experiments on the velocity of transmission of electrical impulses through long conductors, it is probable that the first part, as it were, of the electrical wave reaches the distant station in an inappreciable moment of time, but that in order to overcome the inertia, and give perceptible motion to the signal apparatus, an accumulation of power is required. The time necessary to this accumulation will depend on the weight, and other causes of resistance in the apparatus, and also on the intensity of the electrical current; hence, the two instruments ought to have precisely the same degree of sensitiveness, and the battery during the continuance of the experiment should retain the same electro-motive power.

The method of telegraphing, employed with the cable, is that devised by Sir William Thomson, of Glasgow, and is founded on the application of the principle of reflection first applied to instruments of precision by our countryman, Joseph Saxton, of the Coast Survey. It consists of a mirror of about half an inch in diameter, to the back of which is attached a small magnetic needle, the joint weight of the two being less than one grain, which is suspended, by a single fiber from the cocoon, in the center of a coil of many spires of fine wire, forming part of the galvanic circuit. Upon this mirror is thrown a beam of light through a slit in front of a bright kerosene lamp, and the deflections of the needle are noted by the movements of the reflected beam received upon a slip of white paper. The exquisite delicacy of this galvanometer, as well as the conducting power of the telegraphic cable, may be appreciated from the result of an experiment in which signals were sent from Ireland to Newfoundland, a distance of 2,160 miles, by means of a battery composed of an ordinary percussion gun cap, in which was inserted a morsel of zinc and a drop of acidulated water.

For determining the time in these observations, a small transit instrument, a chronograph, and an astronomical clock were required at each station, for the accommodation of which a temporary observatory was erected. The observations on the American side were in charge of Mr. G. W. Dean, with the assistance of Mr. E. Goodfellow, while those on the coast of Ireland, as well as the general direction of the enterprise, were under the charge of Dr. Gould, assisted by Mr. A. T. Mosman. The use of the cable was freely granted by the Anglo-American Company, and Dr. Gould received from the astronomer royal, Dr. Airy, and

the electricians of the company, all the facilities and assistance necessary to the undertaking. The report contains a series of investigations relative to the time of transmission of signals, and other points, which can only be properly understood by a study of the work itself.

The Annual Report for the year 1868 was printed, as usual, by order of Congress, and the extra number of ten thousand copies ordered. I would again urge upon Congress the propriety of increasing the number of copies, since the demand has become so great that it is impossible, with the number above mentioned, to meet the applications for them of the correspondents of the Institution or of the constituents of the members of Congress themselves.

In addition to the report of the Secretary giving an account of the operations, expenditures, and condition of the Institution for the year, and the proceedings of the Board of Regents, it contains the following articles: List of Smithsonian meteorological stations and observers in North America and adjacent islands, from 1849 up to the end of 1868; Memoirs of Cuvier, and history of his works, of Oersted, Schönbein, Encke, and Hodgkinson; Articles on recent progress in relation to the theory of heat; Principles of the mechanical theory of heat; Continuous vibratory movement of all matter; Radiation; Synthetic experiments relative to meteorites; Catalogue of meteorites in Yale College; The electric resonance of mountains; Experiments on aneroid barometers; Anniversary address of the president of the Royal Society of Victoria; Report of the transactions of the Society of Physics and Natural History of Geneva, and of the Anthropological Society of Paris; An original communication on drilling in stone without metal, and on a deposit of agricultural flint implements in Southern Illinois, by Charles Rau; Notice of the Blackmore Museum, England; Programmes of several foreign societies; An account of the assay of coins at the United States Mint; Table of foreign coins; and a complete list of the publications of the Smithsonian Institution.

INTERNATIONAL EXCHANGES.—The two objects of the bequest of Smithson, as briefly, though clearly, expressed in his will by the terms "increase" and "diffusion" of knowledge, are both fully provided for in the plan of organization. The *increase* of knowledge is principally effected by the researches that are instituted at the expense of the Smithson fund in the various branches of science, and the *diffusion* of knowledge by the publication of the results of these researches and their distribution to all the principal libraries of the world, and still more generally by the great system of international exchange which has been established. The effect of this system, in its present enlarged dimensions, in the way of facilitating direct correspondence between the scientific men of the Old and New World, can scarcely be overestimated.

During the year that has just closed, 1,734 packages, containing many thousand different articles, have been transmitted to 1,569 parties in

foreign countries. These packages were contained in 112 boxes, having a cubical content in the aggregate of 1,033 feet, and weighing 23,376 pounds. The packages were not only from institutions within the limits of the United States, but also from those in Canada, Central and South America. The parcels received at the Institution for parties in this country numbered 2,600, about one-third more than were received during the preceding year. The separate volumes, parts of volumes, and pamphlets contained in these parcels would amount to many times the number just given, those for the Institution alone amounting, as will be subsequently stated, to 5,555. When it is considered that these works are the published original records of the discoveries of the day in the various branches of science; that they mark the progress of man in a higher civilization, and that the system of exchange tends to unite in one effort, as it were, the labors of those who are endeavoring to enlarge the bounds of knowledge, it is impossible to conceive of a system more efficient or better calculated for realizing one of the conceptions of Smithson, that of diffusing knowledge among men.

The exchanges thus far have principally been confined to books, although large numbers of specimens have been sent abroad on the part of the Institution. Full returns have not yet been asked for these, but one of the conditions on which the specimens are given is that whenever the government shall see fit to make provision for the full support of a national museum, then specimens will be required in return. It is proper to state, however, that in all cases in which the Institution has signified its desire to obtain specimens for special investigations, or for the illustration of a particular subject, such as geology and anthropology, liberal responses have been made.

The Smithson packages, with the single exception of those for Italy, are passed through all the custom-houses of the world free of duty and without examination; and this exception will, we think, be removed as soon as the negotiations now in progress are completed. Efficient aid during 1869, as in previous years, has been rendered the Institution in the transportation of its packages to and from the United States, free of charge, by the following companies, viz: The Pacific Mail Steamship Company, North German Lloyd, Hamburg American Steamship Company, General Transatlantic Steamship Company, Pacific Steam Navigation Company, Inman Steamship Company, Cunard Steamship Company, California and Mexico Steamship Company, Panama Railroad Company, Mexican Steamship Company, Union Pacific Railroad, United States and Brazil Steamship Company, North German Lloyd, (Baltimore line,) and the Atlantic Mail Steamship Company. It gives me much pleasure to make this public statement in regard to an act which deserves commendation, not only on account of the liberal spirit which it manifests, but also on that of the enlightened appreciation which it evinces of the objects of the Institution. Notwithstanding the aid which has been thus liberally extended, the cost of the exchanges now amounts to about $5,000 per annum.

The following are the centers to which the Smithson invoices are consigned: Leipsic, care of Dr. Felix Flügel; London, care of William Wesley; Paris, care of Gustave Bossange; Amsterdam, care of Frederic Müller; Milan, care of L. dell' Acqua; Christiana, care of Professor Holst, of the University. The packages for Asia, Africa, and Oceanica are principally sent through London or the American Missionary Societies. The invoices to South America are forwarded, through the gratuitous services of Mr. Hillier, of the New York custom-house, by regular trading vessels from that city.

In 1867 a proposition was made to the Institution by the Librarian of Congress relative to establishing and conducting a system of exchange of official documents between the government of the United States and that of other nations. In accordance with this, a circular was addressed to the different governments having relations with the United States for the purpose of ascertaining their views as to such an exchange. In every case the proposition was regarded with favor, and at the ensuing session of Congress an act was passed directing that fifty full sets of all documents published at the Government Printing Office should be set apart for the purpose in question, and appropriating a sufficient sum to defray the necessary expenses. Unfortunately, however, Congress neglected to direct the Public Printer to strike off the copies requisite for this purpose, in addition to the regular number previously required for the use of the government, and it was not until recently that the necessary legislation was procured to remedy this omission. As soon as the printing and binding of the documents of the last session of Congress are completed the proposed exchange will be initiated. In anticipation of the receipt of the annual supply of the documents of our government, several large packages containing documents of foreign countries have been already received.

On account of the large additions that have been made of late years to the number of societies and other parties in correspondence with the Institution, a new and revised edition of the list of the former became necessary, and this was prepared during the last year. In order to insure accuracy in the titles and localities of the various establishments, proof-slips of the list were sent to the leading foreign societies through our agents, and also to the diplomatic representatives in this country. In all cases prompt attention was given to our request, and many important corrections and suggestions were received. This list, which now numbers 1,587 literary and scientific establishments, is not only essential to the Institution in addressing its foreign packages, but also, for a similar purpose, to the libraries and societies in different parts of the United States, Canada, and South America.

LIBRARY.—The works, which have been received from all parts of the world in exchange for the publications of the Institution, after being recorded are transferred to the National Library, agreeably to the

arangements described in former reports. The following is a general statement of the number of books, maps, and charts received through exchange during 1869:

Volumes:		
Octavo	946	
Quarto	245	
Folio	43	
		1,234
Parts of volumes and pamphlets:		
Octavo	3,238	
Quarto	709	
Folio	142	
		4,089
Maps and charts		232
Total		5,555

Of the larger donations received during the year in question are the following:

From Iceland Foundation Library, Reikiavik, 44 volumes and 12 pamphlets.

Swedish Academy of Sciences, Stockholm, 56 volumes and 5 pamphlets.

From the Emperor of Austria, 8 volumes and 9 charts.

Public Library, Stuttgart, 118 volumes.

University, Greifswalde, 114 pamphlets, Inaugural Dissertations.

From the Institut de France, 31 volumes.

Ministère de la Marine et des Colonies, Paris, 6 volumes and 40 pamphlets.

Commission Impériale de l'Exposition Universelle de 1867, Rapports du Jury International, volumes I–XIII.

Société de Statistique, Paris, 13 volumes and 28 pamphlets.

Académie de Montpellier, Faculté de Médecine, 22 volumes, Thèses.

From the Society of Engineers, London, 8 volumes, Transactions.

British Museum, 9 volumes and 8 pamphlets.

Royal Archæological Institute of Great Britain and Ireland, 20 volumes, Journal.

From the Bombay Government, 15 volumes, Selections from the Records of the Bombay Government.

National University, Athens, Greece, 37 volumes and 132 pamphlets.

Legislative Assembly of Canada, 17 volumes.

State of Minnesota, 6 volumes, Plate, Documents.

C. M. Hovey, editor Boston Magazine of Horticulture, Botany, &c., 35 volumes.

The Smithson books have been well cared for by Mr. Spofford, the efficient Librarian of Congress. Several thousand have been bound,

and a large number are now in the hands of the binder, each volume being marked on the back with a stamp indicating that it is a Smithson deposit.

In the arrangement of the National Library the publications of learned societies, of which the Smithson books principally consist, form one chapter of the general collection, which occupies the greater portion of the south wing of the western projection of the Capitol. It is desired by the Institution, as well as by the National Library, that this collection should be as complete as possible in the publications of all learned societies which have existed from their first establishment in Italy, about the middle of the sixteenth century, until the present time. Through the kindness of the older societies of Europe a larger collection of their publications has been made by this Institution than was ever before formed in this country, or, with few exceptions, in any of the cities of the Old World. Still, there are many series wanting, and several of those now in our possession are defective; exertions will therefore be made, through our correspondents, to supply deficiencies. The value of the scientific collections as well as of the general library will be much enhanced by the catalogue of books, and particularly that of subjects now in progress, and which, as we are informed, will be completed during the present year. The third volume of the index of scientific papers, prepared by the Royal Society of London, has been printed and will soon be distributed. The completion of this great work will have an important influence on the use of the National Library, to which it will be especially applicable.

The national library has increased so rapidly during the past three years, that the three-fold space allotted to it in the Capitol is now insufficient for its accommodation. Further room, as we learn, has been asked for, and we would suggest that this might be best secured by the erection of a separate building, in whose plan of construction should be incorporated all the latest improvements for the use and protection of books. But whatever may be done in this way, greater facilities than now exist for the consultation of the library should be afforded, by making it accessible in the evenings to those who are precluded from the use of its collections by their official occupation during the hours at which it is now open.

Gallery of Art.—It was stated in the last report that Mr. W. W. Corcoran, with an enlightened liberality only commensurate with his means, had resolved to found in Washington an institution exclusively devoted to art. This design, which would long since have been carried into execution, was interrupted by the war, the building erected for the purpose having been applied to the uses of the government; but we are gratified in being able to state that the possession of it has been restored to Mr. Corcoran, and that he has placed it in charge of trustees, who are to fill vacancies in their board and direct all the affairs of the establishment.

The gallery will probably be open for exhibition to the public and to students in art during the present year. The establishment of this collection, as we have said in a previous report, will obviate the necessity of expending any of the funds of the Institution in supporting a national gallery, and I would suggest that the same policy which has directed the transfer of the library, the herbarium, and osteological specimens to the National Library, the Agricultural Department, and the Medical Museum, be also extended to the Corcoran Gallery. The Institution has a number of pictures and a large collection of plaster busts, which are scarcely in place in the midst of specimens of natural history, but which would produce a better effect in connection with other works of art of a similar character. There need be no danger as to impoverishing the Institution by this liberal policy, since it is in reality but another method of increasing its usefulness.

The saving which is made by transferring the keeping of the library and botanical collections can scarcely be estimated at less than $12,000 per annum, a sum which adds to the efficiency of the Institution in the way of increasing, by the exchange of its products, the collections of objects of nature and art in the national capital, besides adding to the intellectual wealth of the whole country.

MUSEUM.—During the past year the space occupied by the museum has been enlarged by appropriating to it the portion of the building known as the western connecting range, which consists of a room 61 feet long by 38 feet wide. On either side of this room has been erected a row of (seven) upright cases, and in the middle a series of tables extending the whole length of the apartment. The upright cases on the south side have been entirely filled with ethnological specimens from China and Japan, comprising the presents from the governments of these countries to the President of the United States. In the cases on the north side is arranged a large and valuable collection of the dresses of the Indians of the northwest coast and of the Esquimaux of North America. The table cases are also filled with ethnological specimens, among which are many exhibiting the rarer specimens of Indian workmanship, and also those of prehistoric times, from the explored caverns of France, presented by Professor Lartet.

During the year 1869, 390 packages, containing many new specimens and thousands of duplicates, have been received at the Institution, and of these, as far as time would permit, a single choice series has been selected for the museum; the remainder are placed aside to be classified and made up into labeled sets for distribution. In pursuing this policy, to which the Institution is bound by its office of curator of the government collections, it is impossible to restrict the increase of the museum, and now, notwithstanding the great number of specimens that have been given away, nearly the whole of the available space in the building is filled to overflowing. An appropriation for finishing the large hall in

the second story is, therefore, very desirable, but as this room is wanted for the accommodation of the National Museum, and not for the uses of the Institution, it would be highly improper to finish it by a further encroachment upon the capital of the Smithson fund.

We have mentioned in a previous report that the architecture of the large room, in which the specimens are at present exhibited, is not well adapted to an advantageous display of many of the articles, since a considerable portion of the space is occupied by two rows of colossal columns, between which and the walls the cases, forming alcoves, are placed. The ceiling, however, of the hall in the second story is to be attached to the long, iron girders which span the space from wall to wall, and it will not, therefore, require the introduction of columns. It is hoped that in the finishing of this room the primary object of its use will be kept in view, namely, the exhibition of specimens. There is pleasure in perfect adaptation as well as in æsthetical effect; the two, however, are not incompatible, and a proper conception of the true spirit of architecture will never sacrifice the former to obtain the latter.

Since the date of the last report the museum has been increased by specimens in every branch of natural history and ethnology, especially in those of ornithology and the products of the explorations of mounds. An unusual amount of labor has also been expended on the specimens during the same period. The large number of birds in the drawers, as well as those on exhibition, have been re-poisoned to prevent the attack of insects, while those in the cases have been furnished with new stands, and their plumage brightened by washing them with benzine. The cases themselves have been repaired and painted. The mounting of the archæological collections on boards, and the repairing of the articles of pottery, have been continued, and are now nearly completed. The specimens of quadrupeds belonging to the older collections of the government present rather an unsightly appearance, through injury by insects before they were brought from the Patent Office, and because they were not well prepared. Many of them, however, are very rare, and should be kept until better specimens can be obtained.

No small amount of labor is required, in a large museum, to keep up a descriptive catalogue of the various articles it receives, and to this work alone the entire time of a clerk might properly be devoted. The whole number of entries in the catalogue of the National Museum is now 158,662; and of these 16,265 were made during the last year, while of the specimens of the general collection of which no types have been selected for exhibition many thousands of entries yet remain to be inserted.

By the co-operation previously alluded to in this report, the Army Medical Museum, the Museum of the Agricultural Department, and the National Museum are rendered supplementary to each other, each collecting and preserving articles that are not contained in the others. The Commissioner of Agriculture, General Capron, has shown much

zeal and good faith in carrying out the conditions previously mentioned, on which the transfer of the plants was made, by fitting up a spacious room with cases which contain 600 separate compartments for the reception of as many different families of plants, and by appointing a botanist fully approved by the Institution. Dr. Parry, the botanist in question, was a pupil of Dr. Torrey, and for the last twenty years has been engaged in various government explorations, mostly in the western part of the United States. He was warmly recommended by the first botanists of the country, and, I doubt not, will discharge the duties of his office to the satisfaction of all interested in the advancement of this branch of natural history. He has begun to arrange the plants in systematic order for immediate reference, and finds the number of species to be about 15,000, included in 25,000 specimens. The additions that have been made to the collection during the past year, embracing those which have been supplied by the Institution and the Department itself, according to Dr. Parry number 8,000 specimens, including 3,000 species. Besides the specimens of dried plants transferred to the Agricultural Department, a large and interesting collection of woods, from Mexico and South America, has been added to the deposit.

LECTURES.—Previous to the fire which destroyed the upper portion of the main building, in 1865, courses of free lectures were given by the Institution to the visitors and citizens of Washington. These at first, or as long as the novelty continued, were well attended, but in time, owing, in part, to the difficulty of access, in the winter season, to the building, and the absorption of the public mind by the events of the war, the interest diminished, while the management of the system became much more difficult, inasmuch as it was impossible to prevent the introduction of political subjects. The call, however, on the part of the citizens for lectures has lately been renewed. But it must be evident, on a little reflection and from past experience, that the original plan cannot again be adopted without great inconvenience and an expense not commensurate with the value of the results produced. In order, however, to assist in the establishing in this city, during the present winter, of a course of lectures on scientific subjects, and at a low price of admission, it has been thought advisable to grant a moderate appropriation to the Young Men's Christian Association, to enable it to secure the services of distinguished popular lecturers. The building which has been erected by this society not only serves as an ornament to the city, but supplies a want long felt in affording a spacious hall for lectures, conventions, &c. The lectures to which the Institution contributed were of a scientific character, requiring expensive illustration, and, therefore, though they were well attended, they could not have been given at the low price charged for admission, had not aid been afforded.

EXPLORATIONS AND COLLECTIONS IN NATURAL HISTORY.—In this report, as in other of the Smithsonian reports, a distinction is made between the collections of the Institution and those of the National Museum under its charge. The former consists of the large number of specimens (in some instances including hundreds of duplicates of rare as well as of more common species) which have been collected under the auspices of the Institution or through its special agency. These are studied and classified by experts for the formation of monographs and the determination of species and their geographical distribution; or, as is the case in ethnological specimens, are compared for the purpose of tracing anthropological peculiarities; and, finally, made up into properly labeled sets for distribution to museums in this country and abroad. The organization of explorations and the collection of specimens would be important parts of the operations of the Institution were it entirely disconnected from the National Museum. Natural history and ethnology are interesting branches of knowledge, and justly merit a portion of the Smithson patronage; but the National Museum has no just claim on the Institution other than for a perfect series of all the duplicates collected; and it is too much to ask, in addition to this, that the Smithson fund should continue to provide it with house-room, and, in a large degree, with attendance. The distinction we have made is an obvious one, though it may be difficult, in some instances, to draw a line between the specimens in the museum and those of the Smithsonian collections.

Explorations and collections in Natural History have been continued, as in previous years, by the Institution alone, or in connection with other establishments. In giving an account of what has been done under this head, the geographical order adopted in other of the Smithsonian reports will be followed.

Northwest Coast of America.—Mr. McFarlane and Mr. McDougal still continue to collect specimens of the natural products of the Mackenzie River district. Mr. Ferdinand Bischoff has kept up his researches in Alaska, first at Kodiak, then at Kenai. Major General George H. Thomas, of the United States Army, has rendered especial service in collecting in the same region specimens of coal and of zoölogy. The remainder of the natural history collections of Mr. Dall, referred to in the last report, has been received and found of much interest as an illustration of the natural productions of our new possessions in the Northwest. His collections in ethnology will be mentioned further on. Captain C. M. Scammon has continued his explorations, and has presented interesting collections from Alaska and Puget Sound, in addition to several communications relative to the natural history and habits of the seals of the adjacent coast. Dr. Minor has also continued his valuable contributions from the same region.

Western United States.—The geological survey of the fortieth parallel, under Mr. Clarence King, referred to in the last report, has been continued during this year, and the collections made in zoölogy, botany,

mineralogy, and geology, have been deposited in the Institution. They are now in process of examination, and an account of them will be given in the valuable report of Mr. King, which Congress has ordered to be printed. At the last session of Congress an appropriation of $10,000 was made for the continuance of the geological surveys of Dr. F. V. Hayden. He was instructed by the Department of the Interior, under whose direction the money was to be expended, to examine especially the geology, mineralogy, and agricultural resources of the Territories of Colorado and New Mexico. The exploration began at Cheyenne, Wyoming Territory, and was continued through Denver, the silver and gold mining regions of Georgetown and Central City, the Middle Park, Colorado City, and Fort Union to Santa Fé, returning to Denver by way of the San Luis Valley and South Park. In the language of the Secretary of the Interior, "this exploration, though brief and rapid, was eminently successful, and the collections in geology, mineralogy, botany, and zoölogy were extensive." These collections have been deposited in the Institution, from which they will be sent for examination to persons who have made special study of the branches of natural history and zoölogy to which the specimens pertain.

Mexico and Central America.—The explorations of Colonel Grayson, in Northwestern Mexico, spoken of in previous reports, were continued in the early part of the year, and an additional series of specimens transmitted to the Institution. It is, however, with deep regret we have to announce that the labors of this enthusiastic and enterprising naturalist were suddenly terminated by death, from fever contracted in an attempt to explore the Island of Isabella. By his decease the Institution has lost a highly-valued correspondent, and the cause of science a successful cultivator. He devoted many years of his life to the development of the natural history and physical geography of Northwestern Mexico and the adjacent islands; and it is much to be regretted that he had not lived to complete the work in which he was so much interested. The explorations of Professor Sumichrast, on the Isthmus of Tehuantepec, have been nearly completed, and the large number of well-preserved specimens in all branches of zoölogy, received at the Institution from this region, attest his continued enthusiasm and persevering industry. From our veteran correspondent, Dr. C. Sartorius, of Mirador, important collections have been received during the past year.

South America.—Mr. Hudson, of Buenos Ayres, and Mr. Reeve, of Ecuador, have furnished a continuation of the results of their ornithological explorations in these localities, while an interesting series of the birds of Demerara has been contributed by Colonel Figyelmesy.

Most of the collaborators just mentioned have furnished information in regard to the physical geography and the inhabitants of the country from which the specimens were derived, and in this way the Institution has accumulated a large amount of manuscript material relative to the natural history, geology, and ethnology of the different parts of North America, not generally known.

EXPLORATIONS AND COLLECTIONS IN ETHNOLOGY.—During the past year the effort has been continued to increase the collections of ethnology and archæology of the North American continent. It has been considered of special importance to prosecute this subject, since the remains of the ancient people who have inhabited this continent are every year becoming more rare. The mounds are disappearing in the process of agriculture, in the construction of railways, or in the extension of cities, and their interesting contents destroyed or scattered beyond the hope of future recovery. A very extensive correspondence on this subject has been kept up during the year with persons in every part of North America, soliciting information and specimens, giving directions for examining mounds and shell-heaps, and in several cases making a small appropriation for defraying the expenses of special investigations.

Nearly all the explorers mentioned in previous reports have contributed valuable material in this line. During his visit to the Bay of Fundy, Professor Baird, of this Institution, made extensive explorations among the ancient shell-heaps and gathered some facts and specimens of much importance in connection with the subject of the American Kjoekkenmoedding. In these labors he was assisted by Mr. G. A. Boardman, Professor H. G. Webster, Professor Nelson, Mr. Elias Kinny, Mr. Gardner, Mr. Hallett, and also by Captain Treadway, of the United States revenue service.

As ethnology is a branch of study which, at this time, is occupying popular attention, it may be proper to give a more detailed account than usual of the additions that have been made in this line during the year which has just closed. This account is compiled from the descriptive inventory made by Dr. Foreman, under the direction of Professor Baird, in a record book of the collections. For convenience of reference the geographical division is adopted.

British America, Arctic Region.—Mr. Robert McFarlane, stationed at Fort Anderson, one of the Hudson Bay Company's posts in the McKenzie River district, with unabated perseverance, has continued making collections in natural history and ethnology, and has presented to the Institution, with a liberality which cannot be too much commended, a great number and variety of articles to illustrate the character of the people among whom he has so long resided. Intercourse with traders and others has considerably modified their arts of life, and they now present an example of a people in a state of transition from the stone to the iron age. Among the articles from Mr. McFarlane, which illustrate this change, are knives of pieces of iron hoops, spear-heads and fish-hooks of the same material; pipe-bowls of copper and of pewter, and a drilling apparatus, with an ordinary bow and drills tipped with bits of steel; boxes, of which the parts are fastened together with wooden nails, iron being too precious to be used for this purpose; other boxes, of which the parts are joined in the more ancient fashion by stretching over them, in a moist condition, a casing of leather.

The greater part, however, of the articles are of a primitive character, among which, for out-door use, are dog harness, lassos of moose-hide for large animals, and more slender ones, carrying rounded pieces of bone, nut size, to entangle the legs of geese; different models of the sledge for hauling wood and provisions; a stretcher of deer-skin; bows, with arrows, quivers, and cases; a long line of whalebone for fishing; a net of sinew, with bone fish-hooks, fishing floats, spears, throwing-sticks, spear-rests for the deck of the canoe; a whistle or call used in hunting; snow-shoes and models of canoes; screens of wood to protect the eyes from snow blink, concave on the inner side, with two very narrow slits for looking through. Of the articles relative to indoor occupation are deer-skin boots; white and black wolverine gloves; children's garments, neatly made, of soft materials; capuchons, or coverings for the head; tools, with which this and other work is performed, such as awls, drills, polishing implements, of either jasper or carnelian, frequently of bone; a small leather bag of red paint, with pitch or other cementing material. There are also needles of bone, needle cases of ivory, pouches ornamented with beads, for containing sewing fiber. Bunches of this material, arranged as if for a chignon, appear to belong to articles used by women. A rattle of deer or musk-ox hoofs, used in dancing, and bone implements for gambling, suggest the character of native amusements.

From the same district have been received, through the Rev. W. W. Kirkby, a leather pouch, filled with quills of the porcupine, which are used to ornament moccasins, belts, and fire bags; also a fur coat made by the Dog Rib Indians. There are not many articles of personal decoration, except some labrets, thick buttons of white limestone, and bits of blue glass, cemented together, to be worn in a slit of the corner of the mouth after the manner of a sleeve button.

Alaska.—The collections of Mr. W. H. Dall in the Aleutian Islands, at Norton Sound, and in the Yukon region, mentioned in the last report, have been received and are found to be very extensive and interesting. Those from the Aleutian Islands are specimens of native carving in walrus ivory, which exhibit considerable imitative skill in copying the forms of objects introduced by white traders. Among them are a table knife and two spoons, neatly executed. The greater part, however, of Mr. Dall's collection are from the various tribes of Esquimaux living on the shores of Norton Sound, more particularly the articles of clothing made of furs and leather, prepared from the skins of the deer and other animals. These consist of outer and inner garments, for both sexes, and of boots, gloves, and mittens. It would appear from the specimens that the skins of the larger fishes, and also of the seal, are used for articles of dress, adapting the material to the change required for winter and summer. From the region of the River Yukon there are snow-shoes, moccasins, fur dresses, straw-shoes and boots, for riding and dancing, all made and used by the Mahlemuts. The domestic implements of the people are exhibited in a series of spoons or dippers, made of the

broad horns of the Rocky Mountain sheep, wooden bowls, ladles, platters, cups, and trays; bags and haversacks made of seal or fish skin, of all sizes, universally used by the Esquimaux for keeping provisions and other materials; also earthenware lamps, fire bags with flint, steel, and tinder; tobacco pouches, pipes, and snuff-boxes. The articles made of seal-skin on the coast are imitated farther up the river in the skins of the larger fishes, the intercourse between the localities being difficult since the passes are held by a few trading Indians, who act as middle men in exchanging commodities and as guards to prevent access to the coast. From the Unaleets there are neatly-made housewives of fish-skin, and from the Pastolic Esquimaux a small workbag woven of grass, ivory needle cases ornamented with blue beads, and a store of thread made of filaments of dried sinews. The weapons received are interesting illustrations of the character and habits of the people. The bows in this collection, used by the Esquimaux for killing large birds or fish, are of very unusual weight, and many of the arrows employed in shooting the wild goose are tipped with a blunt knob. The sharp arrow-points are the most beautiful and delicate of any we have seen, and are of obsidian, green jasper, or glass. The seal and fish lines are of the long, flexible stems of a *fucus* which grows in deep water and equals whalebone in tenacity and toughness. The harpoons for striking seals are furnished with a horn or bone termination, carrying a barbed point, the whole being detachable from the shaft. From the Ekogmut there are several of these, with others used in killing the whale; also models of canoes, oars, &c., from the Lower Ingaleeks along the Yukon and the Unaleets on the coast. In the way of personal ornament there are a quantity of red paint and a yoke, or necklace, oval pieces of wood or stone to be inserted in a slit in the lower lip, the nose, or the ear; finger-rings, principally of stone, of two kinds, one of which is used on mourning and the other on ordinary occasions.

Aleutian Islands.—From the Aleutian Islands there are in Mr. Dall's collection several hideous masks of gigantic dimensions used in the ceremonies of the people. Dr. T. T. Minor, surgeon United States revenue steamer Wayanda, Captain Howard, commander, who visited Sitka, Kodiak, Unalaska and some points of the Aleutian group, has furnished collections exhibiting the dress, occupations, and habits of the Coloshes, Nuhegags, and Aleutes. The scarcity of stone implements in this collection is worthy of notice, since but two specimens, a pestle and axe, are all that were found, and these were regarded as very ancient. Among the articles are the following: Heavy corded bows for fishing, armed with three prongs; blunt spears, with barbs, and fish spears ornamented with feathers; lines of sea-weed or kelp, with detachable spear-heads; throwing-sticks, to give a longer leverage in projecting the spear. There are also chisels for making apertures in the ice, to which fish resort for air; dog sledges, canoes, paddles, reindeer skin overcoats and boots; an overall perfectly waterproof, and exceedingly light, made

of the intestines of the seal, the edges being sewed or cemented, and the whole ornamented with tufts of hair or feathers in brilliant colors. Glimpses of in-door arts and employments are obtained from specimens of carvings, baskets, woven articles, sewing, paintings, and implements, together with the ever-present pipe, of which there is one with a decorated stem, carved by a Colosh. The illustrations are further extended by wooden trays and dishes, ornamented with carved figures of animals; water-tight baskets, in which provisions are boiled by dropping red-hot stones into the water; mats of simple checquer pattern; carved handles of the black horn of the Rocky Mountain goat, exhibiting an intricate series of ornaments, and fastened by the aid of heat and pressure to the broader horn of the moose, or of the Rocky Mountain sheep, to form a spoon or a ladle. Among the carvings is a remarkable series in walrus ivory of objects in miniature, representing table knives, spoons, candlesticks, boiling kettles, with covers, copied from objects introduced by foreigners; also the animals of the country, such as beaver, moose, whales, seals; a female otter followed by her young; likewise a man spearing a bear; a group of men attacking a reindeer, and several other human figures. These miniature specimens of carvings, which are executed with great neatness and fidelity, evince a minute observation of nature, as well as considerable skill in art. A Colosh painter's kit belonging to this collection, contains a number of brushes very neatly made and of sizes suitable for fine or coarse work. Although the assortment of colors is small, being limited to red, blue, yellow, and black, yet the whole collection of specimens relative to art shows an advance in this line beyond anything before observed in the northern races. Among other articles is the dance rattle, commonly used by the coast tribes, and consisting of a hollow, oval, wooden box, usually in the form of a bird, gaily painted, containing pebbles; also head ornaments, of grotesque form; head dresses, with wooden masks, having distorted features; likewise ornaments of stone finely executed, and representing birds, fish, and serpents in the form of a ring; besides numerous samples of the same in wood and bone.

From Lieutenant T. M. Ring, United States Army, stationed at Fort Wrangel, in Alaska, we have received an important collection of objects, among which are models of the *bardoska*, or canoe, with paddles, of very neat workmanship; the head of a fish spear, and several bullets made of copper; two fish-hooks of a metal resembling silver, and halibut hooks of wood; also two specimens illustrating the form in which provisions are preserved for winter use, one of which is a spherical ball of the fruit of *Rubus chamamorus*, and the other is the compressed inner bark of a coniferous tree, which may serve to allay hunger by distending the stomach. A stone hammer and two pestles are samples of articles still in use, and an ancient barbed and notched bone fish spear exhibits the forms of similar implements discovered in the prehistoric caves of Europe. A full series of carved wooden dishes

and of horn spoons illustrate the table service of the natives, while masks, rattles of wood and of basket-work, neck and lip ornaments of stone, a dressed doll with a head carved in stone, a human image, and a bird of the same material, exhibit some of the occupations and amusements of this primitive people. From Mr. E. E. Smith, of the scientific corps of the Western Union Telegraph Company, the Institution has received a bow and arrows of the Smagamut Indians, for shooting wild geese; and from Dr. A. H. Hoff, United States Army, a very fine sample of the membranous waterproof dresses used by the Alaskans, also a pair of carved chop-sticks of whalebone. The latter articles were received through the officers of the Army Medical Museum.

Washington Territory.—From this quarter we have obtained collections made by Dr. J. T. Ghiselin, United States Army, stationed in Washington Territory, consisting of bow, quiver and arrows in use among the Flathead Indians; also, a number of arrow-heads and a pair of moccasins, collected among the Cascade Indians; we have also a riding whip, wedding hat or bonnet, a berry basket, and specimens of food preserved for winter, consisting of the eggs of the salmon, of the size and consistence of dried peas. Dr. Whitehead, United States Army, also transmits from the same region some bones exhumed from a shell mound, and a metal spoon from an Indian grave.

Idaho Territory.—From among the Nez Percés, Dr. E. Storror, United States Army, has collected specimens of preserved food, consisting of the bulbs of the camas, *Scilla esculenta*, and the kouse bread, an unleavened mass, an inch thick, of the seeds of wild rice, *Zezania aquatica*, pounded up with water, and baked. Accompanying these are spear-heads of flint and iron, strong hair rope or lariat, a woman's saddle, blanket, panniers, a drum, a carved pipe stick, and a handsome pipe of red stone, a skull cap of woven grass, a comb, sewing awl, thread, an ornamented belt worn by a woman, and a model of a cradle, affording glimpses of domestic life. Dr. C. Wagner, United States Army, has forwarded a bow, quiver, arrows, and arrow-heads, obtained from the Snake Indians; and Hospital Steward E. Lyons, a basket, woven scoop, and bow and arrow from the same tribe. From Montana, Dr. R. B. Hitz has transmitted a stone pestle.

Utah Territory.—Dr. H. E. Waters, United States Army, stationed at Fort Bridger, in Wyoming Territory, has collected and forwarded some of the implements of war and the chase used by the Shoshone, Bannock, Ute, and Navajo Indians, consisting of a bow and arrows, a bow case, quiver, tomahawk, and war club. The arrows of the Navajos are said to be poisoned. From Dr. Meacham, United States Army, have been received fragments of pottery found in the same Territory.

Oregon Territory.—Dr. C. Moffat, United States Army, has presented a small but interesting collection from Oregon, near the vicinity of Malheur River and the Stein Mountain. In it we find the bow, quiver, and arrows of the Malheur River Indians, a drinking cup, fire stick, paint

bag, carved wooden comb, and beads; also a specimen of preserved food, consisting of camas root, dried and compressed into a thin cake. These Indians are somewhat away from the beaten route, and everything from them is of much interest.

California.—From mounds in Alameda County, California, examined by Dr. L. G. Yates, who has frequently contributed articles of interest from that State, we have received many specimens of the ancient stone age, consisting of stone pestles, perforators or awls, sinkers, a phallus, spindles, a soapstone ladle, stone mortar and pestle, pipe bowls, shell and perforated stone ornaments, an ancient awl and serrated implements of bone. The race of Indians at present occupying the country are said to be entirely ignorant of the art of making these objects and of their use. From the Pott River Indians, California, Dr. Powell, United States Army, has sent a bow, quiver and arrows; and from the Pah Utes of Owen's Valley, California, we have similar weapons from Dr. Th. McMillan, United States Army, who has likewise contributed a war club of the Mohaves.

Nevada.—Clarence King, esq., director of the United States geological survey in Nevada, presented a portion of a beautifully worked pestle of syenite, obtained in Lower California.

Dakota.—The post surgeons stationed at the military posts on the Upper Missouri, chiefly within the Territory of Dakota, have shown much zeal in collecting objects to illustrate the pursuits and customs of the numerous tribes occupying the country bordering on this river. First among these, in point of interest, are the collections of Surgeon C. C. Gray and Dr. Matthews, United States Army, stationed for some time at Fort Berthold. From the Mandans they have furnished a head dress mounted with buffalo horns, with an ornamental pendant of dressed buffalo hide falling behind the head; a war shield of the Gros Ventres, with bow, case, quiver and arrows, in the highest style of Indian ornamentation; a bow of the Arickarees, ingeniously fashioned of an elk horn; a stone hatchet from the same, together with the scalp taken from a Blackfoot Indian; also from the Yanktonnais Sioux, a hoe, made of the shoulder blade of an elk, accompanied by a wooden saddle and appendages, a pad saddle, a whip with a horn handle, parfleche meat case, sheath for a scalp knife, and a rake of wooden material. The Mandans and the Berthold Indians generally, are addicted to gambling, and accordingly in the collection there are dice, and a small basket to contain them; also the gambling implements in use among the women; and, finally, a wheel or roulette, the workmanship of Gros Ventres. There are also domestic implements of the same tribe, consisting of a basket for carrying provisions, a wooden desk, an earthen pot, implements of bone for scraping skins, with horn spoons and ladles; several medicine rattles, indicating the superstitions of the tribe, and a musical instrument of their invention, illustrating the innate tendency to cultivate the fine arts; while children's toys, including a popgun, not unlike those

in use among the whites, show the unity of intellect among races the most widely separated. A needle case, porcupine quills, and bead ornaments, together with a corn bag, illustrating female occupation, are from Hospital Steward J. E. Jones. From the same Territory, Dr. J. P. Kimball, United States Army, has contributed a large number of objects, such as the bow, quiver and arrows of the Assiniboines; also of the Sioux, Mandans, and Arickarees; scalpknife, sheath, and scalp, of Yankton; war club, bonnet, shirt, and leggings, drum, and other fighting equipments; a fleshing knife for dressing skins, a pemmican mallet, wooden cups, dishes, ladles, spoons, pipe and stems, a peace pipe of the Blackfoot Indians, two pairs of ornamental moccasins, and an ornamented dance rattle. From Fort Wadsworth, Dr. A. J. Comfort, United States Army, has sent a bow, case, quiver and arrows; a collar made of bears' claws; an ornamented sheath for knife; stone hammer; stone spear and arrow-heads; several riding whips; the instruments used in games of ball; a perforated horn implement from a mound; two red stone pipes with carved stems; three ornamented pouches of beaver and other skins; a stone palm thimble for sewing with a large needle; a worked quilt, a bunch of perfumed dried grass, scalp feathers, and a gourd dance rattle, which closes the list. From the Upper Sioux, Dr. James F. Boughter, at Fort Dakota, has obtained for the Institution from the Sioux a bow, with case and arrows, leggings, embroidered with beads; saddle cloths handsomely ornamented, riding whips, war feathers, knife sheath, moccasins, ear rings, &c., the trappings of the warrior. Dr. A. B. Campbell, United States Army, contributes from the Yanktons a handsome necklace of the claws of the grizzly bear; a smoking pipe; war club armed with knives; stone war mace; stone hammer or mallet; a mortar and pestle, the former made of a stout piece of buffalo hide gathered at the corners; with the usual bow and arrows of this tribe, and three arrows of the Kaw Indians. From the vicinity of Fort Randall, Dr. G. P. Hardenburgh has obtained for us another head dress of buffalo skin with the hair on, and surmounted by the horns, with a broad pendant of skin furred and feathered to hang down the neck; also a rubbing stone for dressing skins, and a horn spoon.

Dr. Gardner, United States Army, has forwarded from the same Territory a Chippewa bow, quiver and arrows, saddle, drum and sticks, a Sissiton pipe stick, medicine bag, bow, and a heavy scraper of bone, used in dressing skins. Dr. W. H. Forwood, United States Army, has contributed a bow, bow case, quiver and arrows of the Cheyennes, also arrows from the Sioux; Dr. H. G. Schell, United States Army, from near Fort Laramie, has sent a collection consisting of the bow, bow case, quiver and arrows of the Ogalalla band of Sioux; Dr. C. S. De Graw, United States Army, a bow and quiver of the Kiowas; Dr. A. Muller, United States Army, a hickory war bow of the Yanktons and Sissitons. From the same tribes a battle ax and pouch has been presented by F. B.

McGuire. Brevet Brigadier General Crane has contributed a pair of moccasins and a pipe of the chief Little Bear; Dr. A. Muller sends from Fort Ridgely arrows used by the Yanktons, Sissitons, and Upper and Lower Sioux. Mr. W. L. Toole, from the same Territory, has furnished a handsome red stone pipe, stone ax, chisel, and a stone war club or *casse-tête.*

Upper Missouri River.—From this region, Captain Little, United States Army, has contributed a slab of sandstone, upon which the impression of two human feet are rudely carved. Mr. Leopold Biddle, a stone chisel; and Dr. F. V. Hayden, a very perfectly preserved soapstone vessel, fragments of pottery, arrow-heads, and other objects from the site of an ancient Pawnee village.

Nebraska.—From Nebraska, Dr. S. M. Horton, United States Army, has furnished several important and interesting articles from the Ogalalla band of the Sioux. Among these are a buffalo robe, as prepared by the Cheyennes; a saddle from the Crow Indians; a Sioux war club; a pouch, knife and sheath, and a bunch of feathers, used in taking scalps; specimens of arrows of the Crows, Sioux, Cheyennes, and other tribes; several pairs of moccasins, and a skin prepared for making others; a gun case of Sioux construction; a riding whip; a lariat; provision case of tanned buffalo hide; tanned skins of the Rocky Mountain sheep and of the elk, and smaller articles consisting of several stone pipes from the Arapahoes, a paint bag and a comb, used by the Crow Indians, the latter made of the stiff appendages on the tail of a porcupine.

Kansas.—From the vicinity of Walnut Creek in this State, we have received through Dr. G. M. Sternberg, United States Army, the burial case and its appendages of a male Cheyenne child about three years of age. The wrappings enveloping the body, and the articles of dress, ornament, or daily use which accompanied it, form the most curious and interesting assemblage of objects of the kind we have ever received. The burial case is made of long flexible withes of willow, stripped of the bark, and lashed together somewhat in basket fashion, built up from an oval base, five feet in the longer and three feet in the shorter diameter, the sides and top being arched and rounded, rising about three and a half feet from the base. An opening on one side is left for the introduction of the corpse and a large number of articles of the greatest value to the Indians. These articles consisted of seven highly-finished and valuable buffalo robes; six blankets, white, red and blue; a hood, ornamented with beads; a cape; several worsted scarfs; belts, ornamented with beads and metal disks; a leather belt, covered with metal buttons; apparently all the child's wardrobe, as jackets, underclothes, stockings, moccasins, fur cap, leather gloves; together with a small tin dish, beads, metal plates, ornaments of German silver, and others made of the shells of the haliotis, which is not found nearer than the Pacific coast. There were also several articles which can scarcely be recognized as the property of so young a child, such as spur straps, tobacco pouches, hide

lariats, paint bags, and an oblong piece of stout bull hide. It is the opinion of Dr. Sternberg, that this sepulchral offering of valuable effects was not solely from the immediate relatives of the deceased, but that being the lineal descendant of a great chief, and heir to his rank in the tribe, many families or bands being present at the burial, contributed of their wealth to signalize their connection with the child's family, and the widespread sorrow at the loss they all had sustained. A full account of this interesting collection, with drawings of the articles, has been prepared for publication by Dr. Otis, of the Medical Museum, in the Institution Contributions to Knowledge.

From Fort Harker, Kansas, Dr. E. B. Foyer, United States Army, has presented a number of the arrows used by the Kaws, Apaches, Cheyennes and Kiowas, which are commonly pointed with iron, and have the feathered end painted with the adopted colors of the band or tribe, so that they can at once be recognized by Indian scrutiny.

Colorado Territory and Adjoining Regions.—The collection of ethnology has also been enriched, through the Army Medical Museum, by specimens from the tribes which occupy the plain on both sides of the Rocky Mountains in Colorado, New Mexico, and Arizona. Dr. B. A. Campbell, United States Army, from the first-named Territory, has sent a singular neck ornament, made of turtle shell, and two fine pouches of mink skin for holding tobacco. From the Kiowas, Dr. W. H. Forwood, United States Army, has presented a whip, a pipe, and a medicine rattle; Dr. F. G. A. Bradford a tobacco pouch, an earthen water vessel, a Navajo necklace, a pair of Cheyenne moccasins, claws of the grizzly bear, and a pair of Sioux moccasins. Dr. Lippincott, United States Army, from the Comanches has presented a whip, and Dr. J. Readles the hat of a medicine man, and a wooden spur. From Twin Springs, near Fort Fetterman, Dr. C. Sutherland, United States Army, has contributed two fine stone lance-heads, and Dr. H. S. Schell six Sioux arrows. Dr. P. Moffatt has presented a bow, neatly made and covered on the convex side with the skin of a rattlesnake ingeniously cemented to the wood. From Mr. James Stevenson, of Dr. Hayden's corps, we have a very fine Arapaho saddle, padded and ornamented with beads. To these may be added several arrows of the Apaches and Comanches, presented by F. B. McGuire, esq., of Washington City.

In New Mexico, the Navajos are the most troublesome Indians that reside within the present boundary of the United States, and in the numerous conflicts between them and our military forces many interesting objects have been captured. Dr. John Brooke, United States Army, has procured for us, from Fort Sumner, Navajo bows and arrows, a bridle bit, and a pair of moccasins; Dr. B. A. Clements, United States Army, a lot of arrows; Dr. J. T. Weed a saddle blanket, shield, two bows, bow-case, quiver and arrows, a belt, and a curiously made shield for the back; Dr. McKee, United States Army, a bow case, quiver and arrows, a rough stone implement for dressing skins, and an earthenware dish.

Mr. M. Kayser, of Santa Fé, has contributed from the same tribe a blanket made of the wool of the native sheep. From the Wachita battle ground, in the Indian Territory, Dr. Lippincott, United States Army, has obtained for us a lot of bows, cases, quivers, iron arrow-heads, metal tubes for nose ornaments, and finger rings of German silver. These all belonged to the tribes engaged in the conflict, namely, the Comanches, Arapahoes, Wachitas, and Kiowas.

From Arizona, the principal contributions in former years were by Dr. E. Palmer, acting as medical officer at the Indian agency. The articles presented last year, by the same explorer, were such as relate mostly to the domestic occupations of the Apaches—a pouch with bullets, bone for dressing skins, awls for sewing, resin for finishing bows and arrows, paint bag, with black and red pigments, the former color being derived from the inspissated juice of the mescal plant, and curious necklace, woven of strips of the inner bark, complete the collection. From Dr. John C. McFerran, United States Army, have been received a battle-ax; and from Dr. E. Coues several Apache arrow-heads. From the western part of the Territory Mr. Manning F. Force has sent a (syenite or porphyry) stone axe of symmetrical shape and beautifully polished. Mr. Henry C. Force, from the Gila River, has presented fragments of pottery and shell ornaments, and, from the Moqui Indians, a small, red, earthenware vase. Mr. H. C. Fernald has given a small stone axe, obtained near the same locality.

From Wisconsin, Dr. R. P. Hoy, of Racine, well known for his researches in aboriginal ethnology, has presented an ancient earthenware vase, nearly entire, having a conical or sugar-loaf bottom, with fragments of another vessel. Dr. Moses Barratt, of Waukesha, has sent numerous stone relics, axes, chisels, arrow-heads, and a stone disk; also an arrow straightener, consisting of two flat pieces of sandstone with semi-cylindrical grooves, through which the shaft is drawn when the stones are fitted together. He has also sent fragments, apparently of brick, which formed part of a wall so ancient as to be attributed to Aztec workmanship.

In Illinois, the Chicago Academy of Sciences, energetically engaged in promoting research in aboriginal remains, has had made electrotype copies of a fine specimen of copper knife, one of which has been presented, through Mr. H. Shimer, to this Institution; also a similar cast of a copper chisel, and a cast in plaster of a remarkable terra-cotta image. From Mount Carmel, Illinois, Mr. Robert Ridgway has presented two fine stone axes, several spear and arrow heads; and from the same place Mr. Granville Turner has sent a hoe of jasper, three spear-heads of chert, and a lot of arrow-heads; also from the same State, Dr. Hall has presented a stone axe, a chisel, and a number of arrow-heads; and J. E. Kendrick, of Des Moines, has contributed a series of specimens of pottery.

From Indiana, Dr. R. M. White, United States Army, has presented

a curious earthenware pipe and a dress ornament; Drs. McCoy and Maxwell, for themselves and friends, a collection of stone hatchets, spear-heads, and other stone relics. The most remarkable objects, however, from this State are from near Cannelton, and consist of two stone mace-heads or *casse-têtes*, of hard ferruginous quartz, perforated through their longer axes, polished and finished in a perfect manner. They were presented by Mr. Hamilton Smith, with other stone relics. From Franklin County, Indiana, Dr. R. Haywood and his friends and neighbors have favored the Institution with a considerable collection of stone implements, many of fine workmanship, among which may be enumerated stone pestles, axes, chisels, spears, and arrow-heads, stone ornaments, and pottery.

From Ohio, Mr. W. R. Limpert has contributed a collection, found at Graveport, of well-finished articles; consisting of a variety of stone pestles, a mortar for grinding paint, a number of stone knives or chisels, and axes, a perforated stone disk, over one hundred arrow-heads, a stone awl, and other miscellaneous objects in stone. From Rev. Dr. Thompson, at Milnersville, Ohio, we have received arrow-heads collected in his vicinity.

From Kentucky, Mr. S. S. Lyon, whose archæological researches in 1868 were of such interest in the mounds of Union County, has forwarded additional articles, consisting of shell disks ornamented by carvings, a fishing sinker of the same material, perforators of stone, and small masses of galena worked into a rounded bead-like form.

From Tennessee, Mr. S. L. Wilkinson, near Clarksville, has sent five spear-points, a large number of arrow-heads, a stone disk, and a mortar for grinding paint. Dr. Curtis has also favored us with a lot of arrow-heads from Knox County. We have likewise to record the liberal donation, by Mr. J. H. Devereux, of a very valuable series of stone implements and other objects, collected by himself, chiefly in Tennessee, though some of the articles were obtained in other Southern States, as well as a few from Ohio and Massachusetts. The perfect condition and fine finish of these articles are remarkable, and they are so numerous as to fill a separate case. They consist of every variety of form of axes, chisels, gouges, knives, spear and arrow-heads, pipes, ornaments for the person, of stone and of pottery articles, many of which are entirely unique.

From Arkansas, Mrs. Governor Throckmorton, of Little Rock, has presented a pestle, grinding stone, and two paint mortars; and from the same State, Mr. J. M. Stanley has sent a quantity of quills of the porcupine, colored for use by the Indians in their embroidery.

In Mississippi, Mr. T. J. R. Keenan, of Brookhaven, has shown zeal in examining the natural and ethnological curiosities of his vicinity, and has presented to us a large number of handsome arrow-heads of brown jasper, a curious cylinder of the same mineral, a stone disk, and a pair of ear pendants made of silver coins by an Indian boy.

In Louisiana, opposite Vicksburg, Dr. E. Swift, United States Army,

has examined the contents of several mounds and Indian graves, from which he obtained for us many interesting articles, the principal of which are earthenware vases in good preservation and of curious forms, approaching that of the vessels common among the tribes of Chili and Peru, evidently for holding water, most of them having very narrow openings, and being spherical in shape; also, stone hammers, chisels, pestles, carved pipes of sandstone, a disk of quartz, bowls and cups of earthenware, &c.

In Texas, Dr. D. H. McElderry, stationed at Fort Griffin, has assiduously collected from the tribes near his post many objects of interest; among which we may enumerate three Comanche war shields painted and ornamented, bows, bow case, arrows, quiver, scalp knife, and sheath, war drum, tomahawk, and riding whip, all of which belong to a warrior's equipment. The other articles are implements for dressing skins; tinder bag; dance ornaments; two head dresses, one made of Comanche hair and the other of a bear's ear; a girdle and pouch made of a Comanche's skin; a square girdle and arm and head ornaments, some of silver plates, with toy bows and arrows, and two rag dolls decorated with Comanche hair. Dr. J. Middleton, of Camp Verde, has presented a saddle obtained from the Kickapoos, and Mr. George Kean, some bony plates of the *Lepidosteus*, or great western gar, having been used by the southern and western Indians as arrow-heads; a fact in accordance with a statement of William Bartram in his travels in Florida during the last century.

In Florida, explorations have recently been made in the shell heaps near Tampa Bay by Dr. William Stimpson and Mr. E. C. Stearns. From the former we have received a curious shell implement formed of the columella of the great *Fasciolaria gigantea*, the use of which is unknown. From Mr. Stearns, a large soapstone vessel, a stone sinker, a spear-head and fragments of pottery. Mr. H. Clark, of the same place, has presented several hammers, a fishing sinker, a number of arrow-heads, and an earthenware vase.

From Alabama, we have received specimens of arrow-heads, principally of jasper or agate, and of good finish, presented by Mr. Isaac Slee, of Baldwin County, and specimens of the same kind from Mr. Henry C. Force, collected in Northern Alabama, and also specimens of pottery and arrow-heads presented by Dr. Reynolds, United States Army.

From Georgia, at St. Simon's Island, a favorite station of the Southern tribes, Dr. C. H. Taylor, United States Army, has forwarded a number of stone axes and arrow-heads, and also pottery from Brunswick County.

From Virginia, Fayette County, Mr. A. G. Grinnan has presented a collection of stone axes, hammers, chisels, and a finely formed fishing sinker made of hematite, of which we have several specimens from localities widely separated, the weight of the material being its great recommendation for this service. Mr. E. C. Meade, of Albemarle

County, has given an Indian hatchet and a lot of arrow-heads. Major H. C. Williams has presented arrow-heads from Fairfax County; Mr. Robert Burford, arrow-heads from Isle of Wight County; and from Mr. C. R. Moore we have received a fine lance-head, a pipe, pipe-stem, and arrow-heads, found on the east shore of Virginia.

From North Carolina, Rev. M. A. Curtis, of Edgecombe County, has presented two stone axes, a collection of arrow-heads, and specimens of pottery.

District of Columbia.—From Mrs. M. H. Schoolcraft, of the District of Columbia, to whose liberality we were previously indebted for large collections, we have received additional specimens of stone hammers, a stone disk, and other implements. From the Agricultural Department we have received a very perfectly finished war mace with handle, its locality being unknown. Contributions of specimens from the District of Columbia, were made this year by Joseph Saxton, esq., of the United States Coast Survey. They include very numerous examples of all the usual stone implements, such as axes, chisels, hatchets, gouges, spear-heads of very great size, tomahawks, several perforated stone implements, disks, a vessel carved out of soapstone, and a great number of arrow-heads collected on both sides of the Potomac River, and of every variety of material accessible to the Indians, mostly of quartz and quartzite, slate, jasper, &c., with a large quantity of pottery fragments.

From Maryland, Mr. F. B. McGuire, of Howard County, has presented numerous arrow-heads; a lot of the same collected at West River has been given by Mr. W. Q. Force. Dr. C. Sutherland, United States Army, has presented a stone battle ax and arrow-heads from near Annapolis, and Mr. John Cameron, of Prince George's County, has given us a collection of over a hundred arrow-heads, neatly arranged for exhibition. From Charles County, we have received from Mr. O. N. Bryan, an industrious collector, many objects of this class, such as stone knives, chisels, spear-points, pestles, hatchets, awls, and a variety of Indian pottery. From the same vicinity, Mr. James Slagle has presented arrow-heads and a quantity of fragments of pottery.

Pennsylvania.—Mr. J. H. McIlvaine, an ardent inquirer into the manners and customs of the aborigines, has presented a fine stone ax and a stone tomahawk from Northumberland County, a flanged stone ring or wheel; a stone wrought into the form of a bird; a slate chopping-knife and a breastplate of shells and beads, with specimens of pottery. From B. Smith, Upper Darby, we acknowledge the receipt of a stone ax and some arrow-heads; from R. Christ, at Nazareth, Pennsylvania, two stone chisels and an ax; from Harry Hoover, a flint knife and arrow-heads, collected in Clearfield County; and from Dr. E. Michener a soapstone dish, a hoe, a number of axes, chisels, pestles, a lot of arrow-heads, a tomahawk, and a polished ornament for the neck.

From New Jersey, at Shrewsbury, Mr. Samuel Wilson has sent us a

number of stone axes, chisels, and arrow-heads, a stone tomahawk, paint mortar, and pipe. From Tuckerton, Mrs. Lewis Blackman has presented a stone hoe, a sinker, numerous arrow-heads, and other stone implements. To Isaac Lea, LL. D., of Philadelphia, we are indebted for a very fine stone ax found in New Jersey.

From New York, Messrs. S. P. Forman and R. Howell, near Nichols, have contributed ethnological articles, consisting of stone fleshing chisels, arrow-heads, and flint knives; and also, from Mr. Merritt, near Farmingdale, we have a number of arrow-heads. From Western New York, Dr. F. B. Hough, a diligent coöperator and accurate observer, who long since began to make contributions to the Institution, has forwarded from his extensive collections a number of interesting objects. We may mention a bowl, or deep dish, carved in soapstone; a stone mortar, a number of pipe-bowls, pipes, &c., with chisels, spear-heads, gouges, and an Indian cradle profusely ornamented.

From New England, Mr. S. A. Ladd, from the vicinity of Meredith Village, New Hampshire, has contributed a considerable variety of stone implements, including two of those remarkable chisels, or gouges, having a curved cutting edge; also straight chisels, spear-heads, pestles, fishing sinkers, perforated stone ornaments, and arrow-heads. From Vermont, sent by Messrs. J. M. Currier, W. G. Norris, and R. Wheeler, we have received a spear-head of native copper, of good workmanship, but much corroded. The metal of this may have been obtained in barter from the Indians of Lake Superior, or from others living in Nova Scotia, where the native metal exists. It was accompanied by a stone hoe, a flat, triangular implement with a cutting edge, of which examples are somewhat rare, stone pestles, and lance-heads. Mr. Fearing Burr has presented a cast in plaster of the most perfectly shaped pestle yet obtained, which, at the end grasped by the hand, is worked to a sharp edge or comb, pointed at one side. It was exhumed from an ancient Indian cemetery near Hingham. Very large collections of stone implements have been received from Dr. W. Wood, of East Windsor Hill, Connecticut, who has devoted much time and exhibited great zeal in this branch of research as well as in others connected with natural history. A liberal donation is recorded from him of axes, hammers, chisels, spear-heads, knives, gouges, pestles, perforated stones and hoes, and from these and other parcels received from him, it may be justly inferred that his vicinity was densely populated in former times by the savages who wrought these articles.

Canada, New Brunswick, &c.—Much attention has been excited in the Dominion of Canada upon the subject of aboriginal remains, chiefly through the exertions of Principal Dawson, of McGill University, Montreal, from whom a valuable series of Indian pottery, pipes of stone and earthenware, perforated stone implements, &c., has been received. Professor L. W. Bailey, of New Brunswick, also has presented several stone axes, strings of wampum, spear-points, and arrow-heads, which

were collected in his vicinity. From a long-esteemed correspondent of the Institution, Mr. W. E. Guest, formerly of Ogdensburg, New York, now of Canada, have been received a number of curiously-worked bone implements, chiefly awls or perforators, employed anciently in sewing leather garments and moccasins. An unknown donor has sent us a fine sample of the heavy stone mauls used by the mound builders or their predecessors, in mining the native metallic copper from the Lake Superior region, where the vast deposits of this metal were resorted to for the materials out of which to make spears, tomahawks, fish-hooks, sinkers, and personal ornaments.

Mexico.—From other districts not included within the United States, the Institution has received important contributions in ethnology. Dr. Sartorius, from near Mirador, in Mexico, has sent specimens of the stone implements and ornaments formerly in use among the aboriginal races of that country. Some of these, namely, the perforated ornaments, beads, knives, and chisels, are prepared from a variety of jade—a hard green mineral, held sacred by the natives—and others, such as knives, flakes and arrow-points, are of obsidian, a material from which long-bladed portions can be flaked off by a slight pressure on the sides of the core. The traditional knife for the rite of circumcision among the Jews was of stone, and the suggestion has been made by Dr. Foreman that the custom originated with a people living in Asia Minor or Arabia during the stone age. This collection also contains earthenware images, saucers, incensories, bowls, cups, candlesticks with and without handles, together with domestic utensils made of dried gourds, which are sometimes converted into children's rattles. All these are of modern workmanship and now in use among the people of the country. From Dr. Sumichrast, also of Mexico, we have received a perforated stone tube—probably part of a pipe.

Porto Rico, West Indies.—From Porto Rico, George Latimer, esq., who has long been a very liberal contributor to the collections of the Institution, has sent three additional specimens of remarkable elliptical stone rings, resembling an ordinary horse collar, made from a very hard syenite rock, and carefully sculptured and polished. It is suggested that they were placed on the neck of the human sacrificial victims during religious ceremonies, probably for effecting strangulation before the fatal stroke of the obsidian knife. One of them is of a different pattern, being shaped like a horse-shoe, or the letter U, and of more massive proportions. Included in this interesting collection are also several ancient stone chisels similar to those found in the United States, and a number of terra-cotta images of grotesque form.

From Barbadoes, West Indies, through the kindness of Granville Chester, esq., we have obtained several ornaments of carved shells and a hatchet of the same material. Articles made of shell are now exciting much interest, as this substance seems to have been widely employed at as early a period as that of the age of the mound-builders.

British Guiana.—P. Figyelmesy, esq., United States consul, has presented a valuable series of articles in use among the tribes of Indians now living in the interior of that country, including sets of bows and arrows, war clubs, a blow-gun, with two cases of arrows poisoned with the wourali; an emblem of office, consisting of a club and a paddle combined; a stone chisel, and also head dresses, made of brilliant-colored feathers, bracelets of the green and gold wing cases of a large species of beetle, (*Buprestis*,) beaded aprons worn by females, a necklace of the teeth of the peccary, and a flute constructed of the long bones of a wading bird.

From Central America, Dr. Earl Flint, while examining the Island of Ornatepé, in Lake Nicaragua, obtained for the Institution, from ancient tombs, an idol and three earthenware vases of much interest. From Chiriqui, an unknown donor has contributed an earthenware vase.

France.—The prehistoric caverns and rock shelters of France, under the persevering investigation of Professor E. Lartet, have yielded such a harvest of precious relics, and of ingenious and interesting deductions, as to have conferred on him a world-wide renown. Out of his abundant materials he has with much liberality presented to the Institution several cases filled with objects, of which it will suffice to enumerate a few prominent specimens. Of the animals contemporaneous with man in those obscure times, there are bones of the horse, some of them gnawed by wolves; of the aurochs, rhinoceros, wild goat, chamois, hyena, reindeer, including a very perfect jaw and teeth of the cave-bear. Associated with these are two small bones of the human skeleton, apparently belonging to the phalanges of the hand. Among the implements of war, of domestic use, and articles of ornament, are casts of bone implements, chiefly for making perforations, stone knives, sculptured horn of reindeer, and bone aigrettes, probably for fastening skin or fur dresses; also a mortar for grinding grain or fruits, and casts of arrow-heads, in forms very similar to those of American specimens; and many flakes of flint struck from the core while making knives, arrow-points, or other articles. The European flint is better adapted to this manufacture than any stone found in America, except obsidian. These flint chips were gathered from fourteen different localities in France, indicating the prevalence of the art of forming cutting implements of stone and the density of the population. Professor Lartet has also contributed several large masses of the breccia which occupies the floor of the caves, consisting of bones and teeth of animals, flint flakes, pebbles, and other objects cemented together into a solid pavement. The composition of these masses apparently indicates the great antiquity of man, since they present the stone implements of his construction embedded in the same materials with the bones of the rhinoceros and other extinct animals. The most remarkable portion of this collection may, however, be said to consist of the illustrations of the art of sculpture as it existed among the prehistoric races. The material

employed was the broad portion of the horns of the reindeer or the ivory tusks of the elephant. These carvings exhibit a remarkable appreciation of form and composition, undoubtedly derived from constant observation of the wild animals depicted. They chiefly represent the more remarkable quadrupeds, such as the elephant, reindeer, bear, aurochs, &c. These are all exhibited in motion or in striking attitudes, such as leaping, fighting, or flying from pursuit.

Polynesia.—It is proper here to record an addition to the collections from Commodore John H. Aulick, United States Navy, consisting of a large cape or mantle entirely covered with brilliant plumage of scarlet, gold, and black feathers, derived from birds which are extremely rare in that country. It was made for the personal decoration of King Kamehameha on state occasions, and presented by his Majesty to the commodore when he officially visited the Sandwich Islands, some years ago. From Commodore Magruder, United States Navy, we have received several warlike implements of the Feejee Islands.

METEOROLOGY.—The system inaugurated at the beginning of the Institution has been carried on as usual during the past year. The whole number of observers reporting to the Institution during this period has been 479, and to the Medical Department of the United States Army, 120, making in all 599. Among these, 167 report indications of the barometer and the other instruments, and the remainder those of the thermometer, rain-gauge, and wind-vane. Owing to the necessarily unsettled condition of the army since the war, many changes have taken place in the posts at which observations are made, and therefore the permanent, or, rather, normal condition of the whole system has not yet been established. I say "normal" because, since the observations made for the Institution are from voluntary observers, and some changes must take place in the disposition of troops, therefore more or less variation in the number and locality of points of observation must always occur, and a condition of absolute permanency is not to be expected. Nearly all the material that has been collected by the Institution during the last twenty years is in the hands of computers, with the exception of that relative to the rain-fall, which has been discussed and of which the results are now passing through the press. The material relative to temperature has been put in charge of Mr. Charles A. Schott, and will be completed during the present year, provided the usual number of computers are retained. The discussion of the material relative to the winds of the northern hemisphere, collected by the Institution from various sources, is in charge of Professor Coffin, of Lafayette College, who, with a number of assistants, will press on the work of its reduction and discussion as rapidly as the means appropriated for the purpose will allow. The previous discussion of the winds of the same region by Professor Coffin, published in the transactions of the Institution, has been adopted as a part of the basis of the pilot charts of the British Hydrographic Office, which fact may serve as an indication of the value

attached to the publications of our Institution and to the labors of one of its collaborators. Few persons not having experience in the matter could imagine the amount of labor required in the reduction and discussion of physical observations. In the case of the observations reported to the Smithsonian Institution nearly three millions of figures have to be gone over. But this is not all. Various hypotheses have to be provisionally assumed, and the deductions from them tested by comparison with the actual results of observations; while many special results have to be deduced in accordance with previously established formulas. The result of the discussion of the rain-fall, besides being given in tables, is illustrated by curves and rain-charts. The printing of the tables is necessarily a slow operation, requiring special care in the correction of the proof. The printing of the charts has been facilitated by exhibiting the relative fall of rain in each part of the country by different depths of shading in the original engraving, the distinction being made more obvious by a second printing in a single color. The rain-charts are three in number; one exhibits the relative fall of rain for the whole year; another for the three months of summer; and a third during the months of winter. For agricultural purposes the rain-fall in the summer is most important, but data are given in the tables to ascertain it for every month of the year.

The distribution of rain is very materially affected by the prevailing direction of the wind, and this again is modified by the declination of the sun, a fact which must be evident when we consider that the motive power of the great currents of the aerial ocean is the greater heat of the equatorial regions derived from the perpendicular rays of the sun, which, expanding the air, causes it to ascend and flow over in each direction toward the poles. The medial line along which this expansion takes place must move north and south with the sun in his varying declination. If the earth were covered entirely with water, and were at rest, the currents of the air would be comparatively simple; but, since the earth is in a rapid rotatory motion eastward, the currents which flow at the surface toward the medial line move on one side from the northeast and on the other from the southeast, thus forming what are called the "trade-winds," while the same currents continued upward and northward on one side, and upward and southward on the other, curving eastward, form the great stream of western return-trades which in the northern hemisphere, in summer, continually flow over the United States, at a high elevation, and which waft the higher clouds eastward, giving a similar direction to the principal storms of every season. In midsummer, when the medial line we have referred to is carried northward by the northern declination of the sun, the upper current reaches the earth beyond the fiftieth parallel of latitude, and precipitates the vapor which it brings from the Pacific Ocean in the form of rain on the western coast of America, to the depth, at Sitka, of ninety inches. As the sun declines to the south the rain belt gradually descends along the

coast until it reaches, in diminished quantity, the southern portion of California. As the sun ascends again toward the north the rain also gradually returns northward, until it leaves almost entirely, during the summer, that portion of the western coast south of 50° north latitude.

The primary currents of air we have mentioned are modified by the varying relative temperature of the ocean and the continents. The capacity of water for heat being about six times that of land, the latter becomes relatively much warmer in summer and colder in winter than the former; and since the air at the surface of the earth tends to flow from the colder to the warmer region, there must be a tendency of the wind from the ocean toward the land in summer, and the contrary in winter; though this may not be powerful enough to reverse the general currents, it is yet sufficiently so to produce in them the modifications of a very perceptible character. In summer, the greater heat of the surface of the middle portion of North America keeps the return trade-current at a high elevation, and produces a surface current from the Gulf of Mexico, which, on account of the motion of the earth, assumes a direction from southwest to northeast, bearing with it the moisture which is precipitated in rain, principally throughout the region east of the Mississippi River. Were the earth at rest the same current would flow over the whole of the Mississippi Valley to the base of the Rocky Mountains, and the aridity of the western portion of this region would no longer exist.

In winter, when the upper current, after sweeping across the Pacific Ocean, ascends along the western slopes of the mountains, it precipitates its moisture on their crest in the form of snow, which, melting in summer, gives rise to numerous streams which, although not sufficient to irrigate all the region between the Rocky Mountains and the fertile country adjoining the Mississippi on the west, may yet, by well-directed enterprise, serve very much to circumscribe the arid regions in the Mississippi Valley, as well as to mitigate the droughts of the great interior basins of the mountain system.

In summer, the sun approaching, in its northern declination, a position nearly vertical to the extremity of the Peninsula of Florida, heats the land and produces inflowing and upward currents of air, charged with moisture, which, perhaps more frequently in the after-part of the day, falls in copious showers. In winter, on the contrary, the sun being far south of the latitude of Florida, the surface currents are almost neutralized, or tend to flow from the land, and, hence, the rain-fall at this season is much less.

In the region east of the Mississippi, including the whole Appalachian system, the direction of the surface wind is the same as that of the trend of the mountains, and hence both sides and crests of the latter and intervening valleys are covered with vegetation.

The region along the eastern coast of the United States is also supplied with vapor from the Atlantic Ocean, which is borne inland in all cases where an approaching storm gives rise to a wind from an easterly

direction. The preceding sketch gives a general explanation of the marked contrast between the rain-fall of the eastern and western halves of the United States.

Most of the records of meteorological phenomena which were made previous to a comparatively late date had for their object the determination of, what may be called, the statical condition of the weather in different places, or, in other words, the determination of the average atmospheric pressure, temperature, direction of the wind, and the fall of rain. A knowledge of these elements is of great importance in ascertaining the relative climates of different countries, particularly in regard to sanitary and agricultural considerations. In later years, however, systems of meteorology have been established having more especially for their object the record of the simultaneous conditions of the atmosphere in different portions of the earth, and the origin and progress of storms; that is, to discover, if possible, the dynamic principles which regulate the phenomena of the weather. Systems of this kind have been established in almost every part of Europe and in several parts of Asia, even in Turkey, in the East Indies, and in North America. These systems are not only intended to indicate the laws according to which the atmospheric disturbances are produced, but, also, to predict, by the aid of the telegraph, the weather that may be expected within a given time.

The Smithsonian Institution was the first to make use of the telegraph for this purpose. The state of the barometer and thermometer and the direction of the wind were received from the various telegraphic stations at 8 o'clock each morning and recorded on a large map fastened to a board, into which small iron pins were driven to support circular cards of different colors, which indicated the character of the sky and of the weather—whether cloudy or clear, raining or snowing. On each card was drawn an arrow, the direction of which could be varied by suspending the card from one of eight holes with which it was pierced. A glance at this map showed at once the condition of the sky and direction of the wind over the whole country, and knowing from previous observation the direction of the movement of storms, the weather could, in most cases, be predicted, frequently more than a day in advance. In Europe the prediction of the weather is founded on the probable direction of the wind at a given place as deduced from telegrams giving the maximum and minimum pressures of the air as indicated by the barometer. It has been found from observation that the wind which may be expected will blow nearly at right angles to a line joining the maximum and minimum pressure of the air, and that the face being turned toward the minimum point, the wind will come from the left-hand side. This rule, however, may be theoretically deduced from the movement of the air in the form of a cyclone, but will scarcely hold true in case of the storms observed in the eastern portions of the United States. The storms that visit the west of Europe are those which come directly from the ocean, where the cyclonal character of the

wind finds little disturbance from inequality of surface, while the storms on the opposite American coast have their origin far inland, and are subject to great changes of form by mountains or other obstructions in their passage to the Atlantic Ocean. The system adopted by the Institution for predicting changes in the weather was interrupted by the war, and since the restoration of peace the telegraph companies could not be induced to furnish the transmission of the necessary telegrams free of charge; and as this project was intended as a practical application of science and would require a much larger appropriation for its support than could be afforded by the Smithson fund, the proposition to renew the system has been allowed to rest. At the present session of Congress, however, a resolution was offered by Mr. Paine, of Wisconsin, which was adopted, authorizing an appropriation of $25,000 for a system of weather signals, especially along the northern lakes. The general direction of this system has been placed in charge of the Chief of the Signal Corps of the Army, General Myer. The plans which have been adopted for the carrying out of the proposed object have not been communicated to the Institution. We shall, however, be ready to give any advice or assistance in conducting the enterprise which may be required, and also to avail ourselves of any facilities which it may afford us in the study of the climatology of the northern hemisphere.

Respectfully submitted.

JOSEPH HENRY.

JANUARY, 1870.

APPENDIX TO THE REPORT OF THE SECRETARY.

Table showing the entries in the record books of the Smithsonian Museum in 1868 and 1869.

Class.	1868.	1869.
Skeletons and skulls	8,150	9,708
Mammals	9,300	9,516
Birds	54,000	58,976
Reptiles	7,200	7,517
Fishes	5,625	7,885
Eggs of birds	14,100	15,500
Crustaceans	1,287	1,287
Mollusks	18,500	21,770
Radiates	2,725	2,725
Annelids	110	100
Fossils	7,200	7,283
Minerals	6,625	6,977
Ethnological specimens	7,400	9,233
Plants	175	175
Total	142,397	158,652

The total number of entries during the year thus amounts to 16,255; of which nearly 5,000 are birds and 1,800 ethnological objects; 1,400 eggs, &c.

Approximate table of distributions of duplicate specimens to the end of 1869.

Class.	Distribution to the end of 1868.		Distribution in 1869.		Total.	
	Species.	Specim'ns.	Species.	Specim'ns.	Species.	Specim'ns.
Skulls and skeletons	129	163	25	430	154	593
Mammals	852	1,667	33	39	885	1,706
Birds	10,008	15,440	2,943	3,556	12,951	18,996
Reptiles	1,699	2,822	2	8	1,701	2,830
Fishes	2,424	5,200	10	10	2,434	5,210
Eggs of birds	4,151	10,627	230	1,084	4,381	11,711
Shells	72,970	172,472	5,421	5,455	78,391	177,927
Radiates	551	727	....	....	551	727
Crustaceans	1,013	2,516	10	10	1,023	2,526
Marine invertebrates	1,838	5,152	....	....	1,838	5,152
Plants and packages of seeds	13,658	19,218	....	....	13,658	19,218
Fossils	3,401	9,002	557	982	3,958	9,984
Minerals and rocks	2,118	6,654	762	1,120	2,880	7,774
Ethnology	1,107	1,107	....	47	1,107	1,154
Insects	1,420	2,587	112	259	1,532	2,846
Diatomaceous earth	15	555	11	11	26	566
Total	117,354	255,909	10,116	13,011	127,470	268,920

Additions to the collections of the Smithsonian Institution in 1869.

Alden, Dr. C. H., United States Army.—One box fossil bones and teeth, Wyoming Territory.

Allard, C. T.—Collection of minerals, Illinois.

Athens, Greece; Museum of Natural History.—Fossil bones from Mount Pikermi.

Aulick, Commodore John H., United States Navy.—Feather cape of King Kamehamaha, from Sandwich Islands.

Avey, Adam.—Indian spear head, Indiana.

Baird, Professor S. F.—Skull of mephitis, Massachusetts; portions of skeleton of whale, Grand Manan, New Brunswick; bones, stone implements, &c., from caves near Carlisle, Pennsylvania; 40 skulls of porpoise, Bay of Fundy; bones and relics from shell mounds, Maine.

Barnes, Major General J. K., Surgeon General United States Army.—See *Washington*, Medical Department United States Army.

Barratt, Dr. Moses.—Indian relics and fresh-water shells, Wisconsin.

Bartholf, Dr. John A., United States Army.—*Ardea herodias*, Mississippi.

Beales, A. C., hospital steward United States Army.—Box bird skins, North Carolina.

Behrens, James.—One box insects, California.

Biddle, Leopold.—Carboniferous fossil, stone chisel, &c., Iowa.

Bischoff, Ferd.—Eight boxes zoölogical collections, from Alaska.

Blackburn, George and Charles.—One box birds' eggs, Iowa.

Blackman, Mrs. Leah.—One box Indian stone relics, &c., New Jersey.

Blakeslee, C. T.—One hornet nest, Ohio.

Boardman, G. A.—Indian relics from shell heaps of Maine; and 100 skins of birds from Florida.

Bolles, Rev. E. C.—Box of shells, (*Lymnea ampla*,) Maine.

Boucard, A.—Coleoptera and reptiles from Mexico.

Breslau, K.; Ober-Berg-Amt.—Collection of minerals and fossils of Germany.

Brevoort, J. Carson.—South American deer in flesh.

Bryan, O. N.—Miscellaneous Indian relics, Maryland.

Burr, Fearing.—Cast of Indian stone pestle, Massachusetts.

Byrne, Dr. C. C., United States Army.—Indian stone scrapers, Arkansas.

Cambridge; Herbarium of Harvard College.—One box seeds of acacia, &c., Australia.

Cameron, John.—One card Indian arrow-heads, Maryland.

Canfield, Dr. C. A.—One box marine animals, and two boxes nests and eggs, California.

Capel, J. H.—Bones of elk from Canada.

Capron, General H., Commissioner of Agriculture.—See *Washington*, Department of Agriculture.

Carter, Mr.—One box fossils and minerals from near Fort Bridger.

Charbonnier, Dr. A. V., United States Army.—Minerals and fossils from Mammoth Cave, Kentucky.

Chester, Rev. G. T.—Three shell implements, Barbadoes.

Chicago; Academy of Sciences.—Copy in terra cotta of an image from a mound, Missouri; electrotype cast of copper-knife from mound in Illinois; cast of ancient vase.

Christ, Richard.—Egg of Sawwhet owl, Pennsylvania.

Clark, H.—Indian pottery, stone and shell implements, skulls, &c., Florida.

Collett, John.—Three Indian arrows, trilobites, fossil ferns, &c., Indiana.

Coues, Dr. E.—Two boxes bird skins and osteological collections, North Carolina.

Crocker, Allen.—Fossils and zoölogical specimens, Kansas.

Currier, Dr. J. M.—Indian stone relics, Vermont.

Curtis, Rev. M. A.—Teeth of cyprinoid fish, Indian relics, and Indian beads from a grave, North Carolina.

Dall, W. H.—Paper currency from Pekin, China; and 22 boxes zoölogical and ethnological collections from Alaska.

Davis, J. H.—Skin of panther.

Davis, H.—Fossil coralline, (?) Minnesota.

Davis, Dr. Samuel.—Indian stone relics, Indiana.

DeCrery, P. A.—Specimen of magnetic rock, Martinique.

De la Verney, Mr.—Supposed meteorite, New York.

De Oca, R. Montes.—Mounted peccary, (*Dicotyle torquatas,*) Mexico.

De Selding, Charles.—Skull of dog, Tennessee; bit and reins of bridle from Lima, South America; black slate carved pipe, Northwest Pacific; fishing line, hook, and net, Otaheite.

Deems, J. W.—One box copper and silver ores, &c., Mexico and California.

Denny, Henry.—Set of casts of the great seals of England; skull of dog and portion of pelvis of rhinoceros from Dowkerbottom Cave, England; *Euplectella speciosa*, Philippine Islands; fossil crinoid, (*Woodocrinus,*) from York, England.

Department of Agriculture, General H. Capron.—Mounted rabbit, nest of oriole, stone war-club, &c., Pennsylvania.

Destruge, Dr. A.—Two boxes birds, Ecuador.

Dille, Mr.—Teeth of fossil horse, Illinois.

Dodd, P. S.—Eggs of tern, merganser and ring plover, Nova Scotia.

Edwards, Amory.—Skins of six species of jay, California.

Edwards, Henry.—One box insects, and living *Helix arrosa*, California.

Endres, J. R.—Two boxes of humming birds, Costa Rica.

Fauntleroy, Thomas W., per O. N. Bryan.—Indian mortar, axe, &c., Virginia.

Fernald, Charles.—Neuropterous insects, California.

Figyelmesey, P., United States Consul.—Three boxes birds, insects, and curiosities, British Guiana.

Flint, Dr. Earl.—Ancient pottery and seeds of the turkey flower, Nicaragua.

Force, Henry C.—Shell ornaments from Casa Blanca, near Gila River, with fragments of pottery, stone axe, &c.

Foreman, Stephen.—Indian relics, New York.

Gardner, E. F.—Indian relics from shell heaps, Maine.

Gardner, Dr. W. H., United States Army.—Indian implements and relics, Dakota.

Geisdorf, Dr.—Two skulls of Indians and one beaver skull, Montana Territory.

Ghiselin, Dr. J. T., United States Army.—Indian implements, &c., Oregon.

Giddings, Edward.—Skulls of Nisqually Indian and of mammals; serpula, and casts of shells, Washington Territory.

Gilliss, John R.—Skull and other bones of human skeleton, Utah.

Goss, B. F.—One box birds' eggs, Wisconsin.

Gray, Dr. C. C., United States Army.—Skeleton of Indian child, Dakota.

Grayson, Colonel A. J.—Four boxes birds, insects, &c., Mexico.

Griffith, Amos L.—Nest of humming bird, Tennessee.

Grinnan, A. G.—Indian stone implements, Virginia.

Gruber, Ferdinand.—Six skins *Harporhycheus redivivus*, California; and one box birds, Australia and California.

Hagan, J. W.—Indian stone relics, Kentucky.

Hall, Dr. E.—Indian stone relics, Illinois.

Hancock, E. M.—Birds' eggs, Iowa.

Harper, W. J. W.—One box shells, California.

Hayden, Dr. F. V.—Ancient soapstone bowl, Wyoming Territory; and 22 boxes geological and other collections, Colorado.

Haymond, Leigh.—Indian stone implements, Indiana.

Haymond, Dr. Rufus.—One box Indian stone relics, Indiana.

Heverin, John T.—*Menopoma alleghaniensis*, Missouri.

Holmes, Professor F. S.—Phosphate of lime from Ashley River, South Carolina.

Howe, Rev. S. S.—Indian pipe and other relics, Dakota and Iowa.

Hoxie, Walter.—One box birds and birds' eggs, South Carolina.

Hough, Dr. F. B.—Bones of *Sus* from depth of 18 feet in Loess, and one box Indian relics, New York and Canada.

Hoy, Dr. P. R.—Skull of a Pottawatomie chief and Indian vase from mound; also birds' nests and eggs, Wisconsin.

Hubbard, Dr. E. W.—Helices from various localities.

Hudson, W. H.—Two boxes birds, Buenos Ayres.

Hurt & Bros.—Box iron ore, clay, &c., Virginia.

Jewett, Colonel E.—Corallines in chalcedony, Florida.

Jones, Rev. C. M.—One box birds, Connecticut.

Keenan, T. J. R.—Two boxes insects, one box shells, Mississippi.

Kelley, Dr. A. Way, United States Army.—Fragment of tooth of mastodon, Mississippi.

Kilpatrick, General J.—Mummied child from Arica, Peru.

Kimball, Dr. J. P., United States Army.—Indian scalps, rattle, &c.

King, Clarence.—Twenty-six boxes and two kegs, geological and natural history collections from Utah.

Kirkby, Rev. W. W.—One box specimens natural history, birds' eggs, &c., Fort Simpson, Hudson Bay Territory.

Kluge, Dr. J. P.—Reptiles and insects, Panama.

Knudsen, Valdemar.—Ninety human crania, Sandwich Islands.

Ladd, S. A.—Twelve Indian stone relics, New Hampshire.

Lartet, Prof. E.—One box prehistoric remains, France.

Latimer, George.—One box bird skins and one box stone implements, Porto Rico.

Lawrence, G. N.—*Graculus mexicanus* mounted, Cuba.

Le Carpentier, Jules.—One box beetles, New Mexico.

Lea, Isaac.—Indian stone axe, Pennsylvania; specimen of granite perforated by *Pholas*, Nantes, France.

Lee, Dr. J.—Golden eagle in flesh, Maryland.

Leer, James.—Lignite and iron pyrites, District of Columbia.

Lewis, Dr. James.—One box fresh-water univalves, New York.

Lewis, S. G.—Diallogite and other minerals, California.

Limpert, W. R.—Indian stone relics and eggs of woodcock, mallard, &c., Ohio.

Lincecum, Dr. Gideon.—One box *Lepidoptera*, Texas.

Lincecum, G. W.—Humming birds, and four boxes birds, insects, &c., Texas.

Lockhart, James.—One box insects, Hudson Bay Territory.

London; Royal College of Surgeons, through Professor Flower.—Skulls of lion, tiger, jackall, &c.

Lyons, Dr. W. B.—Fossil saurians, New Mexico.

Lyons, E., Hospital Steward, United States Army.—Indian implements, Dakota.

March, William T.—One box birds, Jamaica.

Matthews, Dr. W., United States Army.—Bird-skins, eggs, &c., Dakota.

Maynard, E. J.—One box bird skins, Florida.

McCoughtry, Miss E. G.—Indian stone implements, Kentucky.

McCoy, Miss E. M.—Indian arrow-heads, Indiana.

McCoy and Maxwell, Drs.—Massasauga rattlesnake, Indiana.

McIlvaine, J. H.—Collection of bird skins and Indian relics, Pennsylvania.

McKee, Dr. J. C., United States Army.—Navajo bracelet, Indian Territory.

McWeen, J. M.—Skull of mound-builder, Indiana.

Merritt, J. C.—Indian arrow-heads, New York.

Moffatt, Dr. P., United States Army.—Indian implements, Oregon.

Michener, Dr. E.—Indian stone relics and type specimen of *Euspiza townsendii*, Pennsylvania.

Michener, Captain J.—Skin of purple gallinule and ancient relics in iron and brass, Maine.

Milborn, Caleb.—Carving in ornamental green marble, Delaware.

Minor, Dr. T. T.—Five boxes ethnology and natural history, two skeletons of sea otter, and box of Indian curiosities, Alaska.

Montreal; McGill University, from Principal Dawson.—One box Indian antiquities, Indian axes, &c., Canada.

Moore, C. R.—Indian pipes, arrow-heads, &c., Eastern Shore of Virginia.

Morris, W. F.—Head of diamond rattlesnake, Mississippi.

Nelson, Peter.—Teeth and bones of mastodon, Florida.

Newsom, W. Lewis.—A cane carved by Andrew Oliver, a revolutionary soldier, and prisoner to the British in 1783, New York.

New York; Central Park Commission.—Two living European swans, New York.

Nichols, Dr.—Raccoon in the flesh, District of Columbia.

Nixon, J. Sharpe.—One bird (*Regulus satrapa*) in flesh, Pennsylvania.

Norris, H. W.—Indian stone relics, Vermont.

Norris, W. G.—Indian stone relics, Vermont.

Orton, Professor.—Collection of bird skins, Ecuador.

Otis, Dr. George A., United States Army.—Four sets bows, bow cases, quivers, and Indian trinkets, from the battle-ground of Washita River, Indian Territory.

Palmer, Dr. E.—One box birds' nests and eggs, Fort Wingate.

Parker, H. G.—Bill of white pelican, &c., Nevada.

Parrish, Henry M.—Egg of screech owl, Alabama.

Philadelphia; Academy of Natural Sciences.—Egg of *Alca impennis*, or great auk, Iceland.

Phillips, M. W. S.—Indian stone relics, Kentucky.

Pitch, Captain, through Agricultural Department.—One crab; Caribbean Sea.

Plumbo, G.—Indian stone relics, Kentucky.

Plummer, R., and Comegys, H. C.—Twenty-three bird skins, Connecticut.

Portland; Society of Natural History.—Postpleiscene fossils, Maine.

Post, Dr. S. A.—Quartz geodes, Syria.

Powell, Dr. R., United States Army.—Bow, quiver, &c., Pitt River Indians, Oregon.

Ravenel, Dr.—Land shells and alcoholic preparations, Texas.

Reeve, J. F.—Collection of bird skins, Ecuador.

Reinert, Dr. Paul.—Three packages of dried plants, Germany.

Reynolds, Dr. R. M.—Indian pottery, arrow-heads, &c., Alabama.

Ridgway, Robert.—One box birds, Illinois.

King, Lieutenant F. M., United States Army.—Forty-two objects Indian curiosities, Alaska.

Robinson, Windham.—Bones of young mastodon, &c., Virginia.

Rothhammer, Dr. S. M.—One Indian soapstone dish, Florida.

Sartorius, Dr. C.—One box specimens of natural history and ethnology, and a specimen of *Lystra cerifera*, Mexico.

Saxton, Joseph.—Indian stone relics, seeds, &c., District of Columbia.

Scammon, Captain C. M.—Rostrum of sword-fish, Pacific Ocean; one keg alcoholic specimens, skulls of seals, skins of fur seal, cetacean skulls, &c., Pacific Coast.

Schlütter, William.—One package birds' nests, Germany.

Schultz, Dr. C. F.—Indian stone axe, Pennsylvania.

Sclater, Dr. P. L.—Nine bird skins, Bogota.

Sessions, Lewis.—Nest and eggs of birds, Connecticut.

Shanks, William.—Indian stone relics, Indiana.

Shimer, H.—Electro copy of an Indian copper knife, Illinois.

Smith, Benjamin H.—Indian stone relics, Pennsylvania.

Smith, Hamilton.—Two polished Indian implements of quartz, Indiana.

St. John; Natural History Society.—Devonian fossil plants, New Brunswick.

Stearns, R. E. C.—Collections of ancient relics from shell heaps; twenty-two species of shells in alcohol, Florida.

Sternberg, Dr. G. M., United States Army.—Burial case of an Indian child, five boxes vertebrate and other fossils, Kansas.

Stevenson, James.—Arapahoe (Indian) saddle, Wyoming Territory.

Stimpson, Dr. William.—Indian shell implement, Florida.

Storrow, Dr. E., United States Army.—Indian implements and relics, Idaho Territory.

Sumichrast, Dr. F.—Three boxes birds, mammals, reptiles, &c., Mexico.

Swift, Dr. E., United States Army.—Indian pottery, stone implements, pipes, &c., Louisiana.

Tate, Ralph.—One box shells, Nicaragua.

Thomas, General G. H., United States Army.—Bones of walrus, and one box coal, Alaska.

Thompson, R. O.—Three fossil shells, Missouri.

Throckmorton, Mrs.—Indian stone mortar, Arkansas.

Todd, Dr. W. H.—Indian relics from shell heaps, Maine.

Totten, Dr. G. M.—Cormorant and flying fish, Straits of Magellan.

Turner, Granville.—Indian stone relics, Illinois.

Unknown.—One box specimens of coal, one box alcoholic specimens insects.

Vanardale, Henry.—Indian stone hatchet, Indiana.

Wagner, Dr. Clinton, United States Army.—Squirrel and bird skins and Indian implements, &c., Idaho Territory.

Wakefield, Dr.—Skin of wren, *Campylorhyncus brunneicapillus*, Sonora.

Warner, John G.—Specimens of rotten stone, Pennsylvania.

Washburn, Hon. Thomas.—Indian arrow-heads, Indiana.

Washington; Army Medical Museum.—See Medical Department United States Army.

Washington; Medical Department United States Army.—See Drs. Alden, Byrne, Cherbonnier, Gardner, Ghiselin, Gray, Kelley, Kimball, Lyons, W. B., McKee, Moffatt, Otis, Powell, Reynolds, Sternberg, Storror, Swift, Wagner, White, Whitehead, and Lyons, E., hospital steward, United States Army.

Washington, Agricultural Department United States.—See Capron, General H., Ravenel, Dr., Geisdorf, Dr.

Wellstood, Stephen.—Cane made of wood of steamer Charlotte Dundas, 1803, Scotland.

Wheeler, Ruel.—Indian stone relics, Vermont.

White, Dr. R. H., United States Army.—Ancient pottery from mound, Alabama.

Whitehead, Dr. W. E., United States Army.—Indian implements, Washington Territory.

Whitney, Joseph.—Indian beads, gouge chisel, &c., Maine.

Wilkinson, S. L.—Collection of Indian relics, minerals, plants, Tennessee.

Williams, H. C.—Stone implement, Virginia.

Wilson, Dr. S. W.—Four living *Amphiuma*, Georgia.

Wilson, Samuel.—Indian stone implements, New Jersey.

Wilson, Thaddeus.—Indian stone relics, New York.

Wingate, John D.—Two salamanders and box of insects, Indiana.

Yates, Dr. L. G.—Indian skulls and fossil ox bones, and Indian stone relics, California.

Yeager, Mr.—Indian arrow-heads, flint-flakes, &c., New York.

Young, Nathan.—Specimens in alcohol, Indiana.

LITERARY AND SCIENTIFIC EXCHANGES.

Table showing the statistics of the Smithsonian exchanges in 1869.

Agent and country.	Number of addresses.	Number of packages.	Number of boxes.	Bulk of boxes in cubic feet.	Weight of boxes in pounds.
Dr. Felix Flügel, Leipsic:					
Russia	73	82	......	....	....
Germany	590	649	......	....	....
Switzerland	60	65	......	....	....
Total	723	796	42	418	10,625
Royal Swedish Society of Sciences, Stockholm:					
Sweden	16	19	2	23	500
Royal University, Christiania:					
Norway	10	14	1	11	250
Royal Danish Society of Sciences, Copenhagen:					
Iceland	1	1	......	....	....
Denmark	20	22	......	....	....
Total	21	23	3	23	626
Frederick Müller, Amsterdam:					
Holland	64	70	......	....	....
Belgium	36	45	......	....	....
Total	100	115	6	66	1,425
Gustave Bossange, Paris:					
France	186	203	......	....	....
Spain	7	9	......	....	....
Portugal	4	5	......	....	....
Total	197	217	9	98	2,500
R. Istituto Lombardo di Scienze e Lettere, Milan:					
Italy	83	85	3	33	825
William Wesley, London:					
Great Britain and Ireland	291	309	16	161	4,025
University of Melbourne:					
Australia and New Zealand	20	41	4	40	1,000
Rest of the world	108	115	20	160	2,000
Grand total	1,569	1,734	112	1,033	23,376

Packages received by the Smithsonian Institution from parties in America, for foreign distribution, in 1869.

Address.	No. of packages.	Address.	No. of packages.
ALBANY, NEW YORK.		HAVANA, CUBA.	
Regents of New York State University	10	Professor F. Poey	1
New York State Library	34	INDIANAPOLIS, INDIANA.	
New York State Agricultural Society	30	Institution for Education of Blind	21
ANN ARBOR, MICHIGAN.		JANESVILLE, WISCONSIN.	
Professor A. Winchell	26	Institution for the Blind	70
BALTIMORE, MARYLAND.		MILWAUKEE, WISCONSIN.	
P. R. Uhler	2	Professor L. A. Lapham	100
BOSTON, MASSACHUSETTS.		MONTREAL, CANADA.	
American Academy of Arts and Sciences	151	Professor J. W. Dawson	1
American Social Science Association	41	NASHVILLE, TENNESSEE.	
American Statistical Association	1	Geological Survey of Tennessee	10
Board of State Charities	63		
Boston Society of Natural History	298	NEW ALBANY, INDIANA.	
Massachusetts Historical Society	11		
Public Library	5	Dr. E. S. Crosier	10
Dr. B. A. Gould	189		
Dr. Howe, (Perkins Institute for Blind)	1	NEW HAVEN, CONNECTICUT.	
S. H. Scudder	93	American Journal of Science	22
		Professor E. J. Brush	2
CAMBRIDGE, MASSACHUSETTS.		Professor J. D. Dana	2
		Professor A. E. Verrill	1
American Association for Advancement of Science	54	NORTHAMPTON, MASSACHUSETTS.	
Harvard College	24		
Museum of Comparative Zoölogy	416	State Lunatic Asylum	14
Professor L. Agassiz			
Alex. Agassiz	16	NEW YORK.	
Professor Wyman	14		
		American Journal of Mines	3
CHARLESTON, SOUTH CAROLINA.		New York Lyceum of Natural History	112
Medical Society of South Carolina	19	American Christian Commission	225
COLUMBUS, OHIO.		United States Sanitary Commission	289
		Thomas Bland	51
Ohio State Agricultural Society	95	T. S. Bickmore	2
Dr. W. B. Sullivant	3	E. Steiger	1
Leo Lesquereux	3		
DORCHESTER, MASSACHUSETTS.		PHILADELPHIA, PENNSYLVANIA.	
Dr. Edward Jarvis	10	Academy of Natural Sciences	248
		American Pharmaceutical Society	19
EASTON, PENNSYLVANIA.		American Philosophical Society	158
		American Entomological Society	15
Professor T. C. Porter	1	Pennsylvania House of Refuge	25

Packages received from parties in America, &c.—Continued.

Address.	No. of packages.
PHILADELPHIA, PA.—Continued.	
Pennsylvania Institute for Deaf and Dumb	25
Public Schools	1
Society for Alleviating Miseries of Public Prisons.	25
Dr. Isaac Lea	199
Dr. John L. Leconte	13
PORTLAND, MAINE.	
Natural History Society.	150
PRINCETON, NEW JERSEY.	
A. D. Brown	12
PROVIDENCE, RHODE ISLAND.	
R. I. Historical Society	3
QUEBEC, CANADA.	
Literary and Historical Society	11
SALEM, MASSACHUSETTS.	
Essex Institute	149
Peabody Academy of Science	115
SAN FRANCISCO, CALIFORNIA.	
California Academy of Natural Sciences	30
Henry Edwards	2
F. Grover	1
ST. LOUIS, MISSOURI.	
Academy of Sciences	190
ST. JOHN, NEW BRUNSWICK.	
Natural History Society	1
ST. PAUL, MINNESOTA.	
Minnesota Historical Society	1
SPRINGFIELD, ILLINOIS.	
Professor H. A. Worthen	1
TORONTO, CANADA.	
Canadian Institute	7
Observatory	10
Dr. C. J. Bethune	2
WASHINGTON, D. C.	
Bureau of Statistics	300
Interior Department	1
Nautical Almanac Office	68
United States Coast Survey	15
United States Agricultural Department	500
United States Department of Education	35
United States Naval Observatory	140
United States Patent Office	1
William H. Dall	142
Dr. F. V. Hayden	6
Dr. C. C. Parry	1
Dr. F. B. Hough	3
WINNEBAGO, ILLINOIS.	
M. L. Bebb	1
Unknown	47
Total	5,220

Packages received by the Smithsonian Institution from Europe, in 1869, for distribution in America.

Address.	No. of packages.
ALBANY, NEW YORK.	
Albany Institute	4
Bureau of Military Statistics	1
Dudley Observatory	30
New York State Agricultural Society	34
New York State Cabinet of Natural History	11
New York State Library	33
New York State University	6
Hon. Francis C. Barlow	1
Professor J. Hall	18
Dr. Thomas Hun	1
AMHERST, MASSACHUSETTS.	
Amherst College	3
Professor E. Hitchcock	2
Professor E. Tuckerman	1
ANNAPOLIS, MARYLAND.	
United States Naval Academy	2
ANN ARBOR, MICHIGAN.	
University of Michigan	4
Observatory	22
Dr. Rominger	3
J. C. Watson	1
Professor A. Winchell	15
ATHENS, ILLINOIS.	
Professor Elihu Hall	2
ATHENS, OHIO.	
Ohio University	1
AUSTIN, NEVADA.	
Dr. J. Storch	1
BALDWIN CITY, KANSAS.	
Baker University	1
BALTIMORE, MARYLAND.	
Maryland Historical Society	3
Peabody Institute	6
University of Maryland	1
Rev. E. A. Dalrymple	1
Professor S. S. Haldeman	1
Dr. J. G. Morris	1
Dr. P. R. Uhler	8
A. Vocke	1
BETHLEHEM, PENNSYLVANIA.	
Dr. Charles M. Wetherill	1
BLOOMINGTON, ILLINOIS.	
Illinois Natural History Society	1
BLOOMINGTON, INDIANA.	
Indiana State University	2
BOSTON, MASSACHUSETTS.	
American Academy of Arts and Sciences	151
American Social Science Association	2
American Statistical Association	8
Board of State Charities	1
Boston Athenæum	1
Boston Mercantile Library Association	1
Boston Society of Natural History	246
Bowditch Library	2
Geological Survey of Massachusetts	2
Massachusetts Historical Society	7
Massachusetts Institute of Technology	1
Massachusetts Society for Prevention of Cruelty to Animals	1
Massachusetts Teacher	1
New England Historic-Genealogical Society	2
North American Review	3
Perkins Institute for Blind	2
Prison Discipline Society	2
Public Library	19
State Library	10
Rev. W. R. Alger	2
Dr. Brewer	2
C. G. Brewster	1
William Brott	1
J. L. Clarke	1
C. Hovey	1
Dr. Charles T. Jackson	1
Dr. J. S. Lombard	1
Miss E. Marmodel	1
John Perry	1
A. P. Rockwell	3
W. B. Rogers	2
F. B. Sanborn	1
S. H. Scudder	4
R. E. C. Stearns	13
Dr. F. H. Storer	1
Walker, Fuller & Co	4
BROOKLYN, NEW YORK.	
Long Island Historical Society	2
James Akhurst	1
H. C. Murphy	1
BRUNSWICK, MAINE.	
Bowdoin College	3
Historical Society of Maine	2

Packages received from Europe, &c.—Continued.

Address.	No. of packages.
BUFFALO, NEW YORK.	
Buffalo Historical Society	1
Natural History Society	1
BURLINGTON, NEW JERSEY.	
W. G. Binney	1
BURLINGTON, VERMONT.	
University of Vermont	3
CAMBRIDGE, MASSACHUSETTS.	
American Association for Advancement of Science	33
Astronomical Journal	2
Harvard College	108
Herbarium of Harvard College	2
Museum of Comparative Zoölogy	30
Observatory of Harvard College	46
A. Agassiz	3
Professor L. Agassiz	68
Dr. E. H. Clark	1
Dr. B. A. Gould	14
Professor Asa Gray	15
Dr. H. Hagen	12
Dr. J. W. Hoyt	1
Dr. Thomas Lyman	3
Dr. G. A. Maack	1
Albert Ordway	1
Professor B. Peirce	2
Professor Jared Sparks	1
Professor J. D. Whitney	3
Dr. J. Winlock	3
Professor J. Wyman	3
CENTRE COUNTY, PENNSYLVANIA.	
Professor H. J. Clark	1
CHAMPAIGN, ILLINOIS.	
State Industrial University	1
CHAPEL HILL, NORTH CAROLINA.	
University of North Carolina	1
CHAPPELL HILL, TEXAS.	
Soulé University	2
CHARLESTON, SOUTH CAROLINA.	
Charleston Museum	2
Elliott Society of Natural History	18
Society Library	1
South Carolina Historical Society	1
CHARLOTTESVILLE, VIRGINIA.	
University of Virginia	3
CHICAGO, ILLINOIS.	
Chicago Academy of Science	75
Chicago Board of Trade	1
Dearborn Observatory	22
University	1
Young Men's Association Library	1
Dr. Andrews	1
Mr. Le Baron	1
Professor F. H. McChesney	1
T. H. Safford	1
Dr. W. Stimpson	5
CINCINNATI, OHIO.	
American Medical College	1
Astronomical Observatory	37
Mercantile Library	1
National Normal	1
Dr. Cleveland Abbe	1
Dr. Rominger	1
CLINTON, NEW YORK.	
Observatory of Hamilton College	9
Dr. C. H. F. Peters	2
COALBURGH, WEST VIRGINIA.	
W. H. Edwards	5
COLUMBIA, MISSOURI.	
Geological Survey of Missouri	2
Missouri University	2
Dr. G. C. Swallow	4
COLUMBIA, SOUTH CAROLINA.	
South Carolina College	1
University of South Carolina	1
COLUMBUS, OHIO.	
Ohio Educational Monthly	1
Ohio State Board of Agriculture	70
Professor Leo Lesquereux	6
John A. Norris	1
Dr. William B. Sullivant	2
CONCORD, NEW HAMPSHIRE.	
New Hampshire Historical Society	1
CREDIT, ONTARIO, CANADA.	
Rev. C. J. S. Bethune	16

Packages received from Europe, &c.—Continued.

Address.	No. of packages.	Address.	No. of packages.
DECORAH, IOWA.		GREENCASTLE, INDIANA.	
Lutheran College	1	Indiana Asbury University	1
DELAWARE, OHIO.		HALIFAX, NOVA SCOTIA.	
Ohio Wesleyan University	1	Nova Scotian Institute of Natural Science	5
Dr. Slotner	1	HAMILTON, NEW YORK.	
DES MOINES, IOWA.		Madison University	1
Geological Survey of Iowa	5	HANOVER, INDIANA.	
Iowa School Journal	1	Frank H. Bradley	2
State Library	18	HANOVER, NEW HAMPSHIRE.	
DETROIT, MICHIGAN.		Dartmouth College	6
Michigan State Agricultural Society	9	Dartmouth Obervatory	1
DORCHESTER, MASSACHUSETTS.		HARLEM, NEW YORK.	
Dr. Edward Jarvis	20	Dr. Seyffarth	1
EASTON, PENNSYLVANIA.		HARRISBURG, PENNSYLVANIA.	
La Fayette College	1	State Library	1
Professor T. C. Porter	2	HARTFORD, CONNECTICUT.	
ENTERPRISE, PENNSYLVANIA.		Young Men's Institute	1
Joseph Gibbons	1	Physical Society	1
ERIE, PENNSYLVANIA.		Mrs. Samuel Colt	1
Rev. L. G. Olmstead	1	HAVANA, CUBA.	
EVANSTON, ILLINOIS.		Dr. Gundlach	1
Oliver Marcy	1	Professor F. Poey	1
FARMINGTON, CONNECTICUT.		HAVERFORD, PENNSYLVANIA.	
Edward Norton	5	Haverford College	1
FORT MACON, NORTH CAROLINA.		HAZLETON, PENNSYLVANIA.	
Dr. Elliott Coues	2	J. N. Porter	1
FRANKFORT, KENTUCKY.		HUDSON, OHIO.	
Geological Survey of Kentucky	11	Western Reserve College	1
GAMBIER, OHIO.		INDEPENDENCE, TEXAS.	
Kenyon College	1	Baylor University	1
GEORGETOWN, D. C.		INDIANAPOLIS, INDIANA.	
Georgetown College	8	Institution for Blind	2
		Dr. W. W. Butterfield	1

Packages received from Europe, &c.—Continued.

Address.	No. of packages.
INMANSVILLE, WISCONSIN.	
Wisconsin Scandinavian Society	1
IOWA CITY, IOWA.	
Grand Lodge of Iowa	1
State University	38
Professor G. Hinrichs	5
Dr. Charles A. White	1
ITHACA, NEW YORK.	
Cornell College	5
JACKSONVILLE, ILLINOIS.	
Institution for Blind	2
JANESVILLE, WISCONSIN.	
Wisconsin Institution for Blind	4
JEFFERSON CITY, MISSOURI.	
Governor of the State of Missouri	1
LEBANON, TENNESSEE.	
Cumberland University	1
Professor James Safford	2
LEXINGTON, KENTUCKY.	
University of Transylvania	1
LEXINGTON, VIRGINIA.	
Washington College	1
M. F. Maury	1
Commodore Semmes	1
LEWISBURG, PENNSYLVANIA.	
University	1
LITTLE ROCK, ARKANSAS.	
State Library	34
LOUISVILLE, KENTUCKY.	
University of Louisville	1
MADISON, WISCONSIN.	
Emigranten	1
Geological Survey of Wisconsin	1
State Historical Society of Wisconsin	10
MADISON, WISCONSIN—Continued.	
State Library	4
University of Wisconsin	1
Wisconsin Natural History Society	2
Wisconsin State Agricultural Society	15
MARIETTA, OHIO.	
Professor E. B. Andrews	6
MIDDLETOWN, CONNECTICUT.	
Wesleyan University	1
MILLEDGEVILLE, GEORGIA.	
Oglethorpe University	1
MILWAUKEE, WISCONSIN.	
German Natural History Society	1
Hon. J. A. Lapham	2
MONTPELIER, VERMONT.	
State Library	5
MONTREAL, CANADA.	
Geological Survey of Canada	3
Natural History Society	16
P. P. Carpenter	1
Professor J. W. Dawson	5
Sir W. E. Logan	5
Dr. Sterry Hunt	2
NASHVILLE, TENNESSEE.	
University of Nashville	1
Dr. Jones	1
NEGAUNEE, MICHIGAN.	
Major T. B. Brooks	1
NEW ALBANY, INDIANA.	
New Albany Society of Natural History	1
NEW BEDFORD, MASSACHUSETTS.	
John H. Thomson	1
NEW BRUNSWICK, NEW JERSEY.	
Geological Survey of New Jersey	4
Professor George H. Cooke	1

Packages received from Europe, &c.—Continued.

Address.	No. of packages.
NEW HAVEN, CONNECTICUT.	
American Journal of Science and Art	66
American Oriental Society	31
Connecticut Academy of Science	32
Yale College	17
Professor G. F. Brush	5
Professor J. D. Dana	43
Professor D. C. Eaton	5
Professor E. Loomis	10
Professor O. C. Marsh	11
Professor A. Newton	6
Professor D. Olmstead	1
Professor Palmer	1
Professor B. Silliman	13
Professor A. C. Twining	2
Professor A. E. Verrill	8
Professor W. D. Whitney	13
NEW ORLEANS, LOUISIANA.	
New Orleans Academy of Sciences	35
NEW OXFORD, PENNSYLVANIA.	
Dr. G. Pfeiffer	1
NORTHAMPTON, MASSACHUSETTS.	
Dr. Earle	1
NEW YORK, NEW YORK.	
American Christian Commission	25
American Ethnological Society	14
American Geographical and Statistical Society	51
American Institute	10
American Journal of Mining	4
American Microscopical Society	4
Astor Library	12
Columbia College	1
Herbarium of Columbia College	1
Lyceum of Natural History	96
Mercantile Library Association	2
The Nation	1
New York Academy of Medicine	5
New York Historical Society	4
Numismatic and Archæological Society	1
School of Mines	4
United States Sanitary Commission	14
University	7
Albert S. Bickmore	2
Thomas Bland	2
Dr. Brown, (Bloomingdale)	1
Dr. John C. Dalton	1
Professor E. C. Day	1
Captain J. M. Dow	2
NEW YORK, N. Y.—Continued.	
Dr. J. W. Draper	5
Dr. Asa Fitch	1
General J. Frémont	6
Dr. Gescheidt	1
Henry Grinnell	6
Dr. William A. Hammond	2
Mr. Harlan	1
Rev. G. C. Holls	1
Dr. Francis Lieber	1
C. Loosey	2
Dr. J. S. Newberry	7
Dr. J. C. Nott	3
Baron R. Osten-Sacken	2
Dr. Paine	1
Messrs. Parker & Douglas	5
Dr. R. W. Raymond	1
Victor C. Reeve	1
Lewis M. Rutherford	3
E. G. Squier	6
Professor George Thurber	1
Professor John Torrey	3
J. Watts de Peyster	2
OSWEGO, NEW YORK.	
Professor Raphael Pumpelly	3
OXFORD, OHIO.	
Miami University	1
OXFORD, MISSISSIPPI.	
University of Mississippi	1
Eugene W. Hilgard	2
PEORIA, ILLINOIS.	
Dr. F. Brendel	1
PHILADELPHIA, PENNSYLVANIA.	
Academy of Natural Sciences	180
American Entomological Society	15
American Journal of Conchology	1
American Journal of Medical Science	2
American Pharmaceutical Association	24
American Philosophical Society	111
Athenæum	1
Central High School	3
Franklin Institute	28
Girard College	1
Historical Society of Pennsylvania	7
House of Refuge	1
Library Company	3
Medical Society of Pennsylvania	1
Mercantile Library	1

Packages received from Europe, &c.—Continued.

Address.	No. of packages.
PHILADELPHIA, PA.—Continued.	
North American Medico-Chirurgical Review	4
Numismatic and Antiquarian Society	3
Observatory of Girard College	2
Pennsylvania Horticultural Society	1
Pennsylvania Institute for Blind	1
Pennsylvania Institute for Deaf and Dumb	1
Pennsylvania Society for Prevention of Cruelty to Animals	1
Philadelphia College of Pharmacy	1
Public Schools	1
University of Pennsylvania	3
Wagner Free Institute of Science	6
E. R. Beadle	1
W. G. Binney	1
L. Blodget	2
H. C. Carey	5
G. W. Childs	4
Dr. E. D. Cope	1
E. T. Cresson	1
Lemuel J. Deal	1
Bennet Dowler	1
W. H. Edwards	2
W. M. Gabb	2
C. F. Hagedorn	1
R. Hare	1
Dr. Isaac Hays	1
Dr. George H. Horn	2
Dr. Isaac Lea	13
Dr. John L. Le Conte	11
Dr. J. Leidy	9
J. P. Lesley	2
B. V. Marsh	1
Dr. J. A. Meigs	4
Dr. S. Weir Mitchell	1
Dr. John H. Packard	1
Dr. M. Richardson	3
Dr. Theiss	1
G. W. Tryon, jr	8
Professor W. Wagner	1
Dr. H. C. Wood	1
PORTLAND, MAINE.	
Maine Journal of Education	1
Portland Society of Natural History	39
Dr. A. C. Hamlin	1
POUGHKEEPSIE, NEW YORK.	
Observatory of Vassar College	1
Miss Maria Mitchell	1
PRINCETON, NEW JERSEY.	
College of New Jersey	10
A. D. Brown	2
Professor A. Guyot	8
PROCTORSVILLE, VIRGINIA.	
Professor Albert D. Hager	1
PROVIDENCE, RHODE ISLAND.	
Brown University	4
Rhode Island Historical Society	3
Rev. Dr. Caswell	1
Stephen Olney	1
Edwin M. Snow	7
QUEBEC, CANADA.	
Literary and Historical Society	3
QUINCY, ILLINOIS.	
Professor Rossmässler	1
RALEIGH, NORTH CAROLINA.	
Dr. Fisher	1
Professor W. C. Kerr	1
RED WING, MINNESOTA.	
Hamline University	1
RICHMOND, VIRGINIA.	
State Library	1
Oswald J. Heinrich	1
ROCHESTER, NEW YORK.	
Dr. Ward	1
ROCK ISLAND, ILLINOIS.	
B. A. Walsh	1
ST. LOUIS, MISSOURI.	
Deutsches Institut zur Beförderung der Wissenchaften	1
Journal of Education	1
St. Louis Academy of Sciences	113
University	3
Ernst von Angelrodt	3
Professor William Chauvenet	2
Dr. G. Engelmann	4
Dr. Holmes	1
Dr. H. A. Prout	1
Maurice Schuster	2
Dr. B. F. Shumard	8
ST. PAUL, MINNESOTA.	
Minnesota Historical Society	6
SALEM, MASSACHUSETTS.	
Essex Institute	61
Peabody Academy of Science	6

Packages received from Europe, &c.—Continued.

Address.	No. of packages.
SALEM, MASS.—Continued.	
Dr. A. S. Packard, jr	14
William S. West	1
SALEM, OREGON.	
Willamette University	1
SAN FRANCISCO, CALIFORNIA.	
California Academy of Sciences	61
Geological Survey of California	1
H. G. Bloomer	1
H. N. Bolander	1
S. Brannan, jr	1
H. Edwards	1
Captain Eldridge	3
Baron Richthofen	1
SANTA BARBARA, CALIFORNIA.	
Alexander Taylor	1
SANTA CLARA, CALIFORNIA.	
University of the Pacific	1
SAUK RAPIDS, MINNESOTA.	
J. H. Kloos	6
SING SING, NEW YORK.	
Dr. G. J. Fisher	9
Dr. W. H. Helm	3
SPRINGFIELD, ILLINOIS.	
Geological Survey of Illinois	1
Illinois State Agricultural Society	1
The Schoolmaster, Normal	1
Professor A. H. Worthen	9
TORONTO, CANADA.	
Canadian Institute	8
Literary and Historical Society	1
Observatory	2
University of Canada	1
Dr. Samuel Wilson	1
TUSCALOOSA, ALABAMA.	
University of Alabama	1
UTICA, NEW YORK.	
American Journal of Insanity	4
Dr. Grey	1
Colonel E. Jewett	1
WASHINGTON, D. C.	
President Grant	3
American Nautical Almanac	8
Bureau of Navigation	4
Bureau of Ordnance and Hydrography	1
Bureau of Statistics	12
Census Bureau	6
Corps of Topographical Engineers	1
Department of Agriculture	142
Department of Education	8
Engineer Bureau	1
Hydrographic Office	9
Interior Department	2
Library of Congress	33
National Academy of Sciences	38
Navy Department	1
Ordnance Bureau	1
Quartermaster General's Office	1
Secretary of the Navy	1
Secretary of State	1
Secretary of the Treasury	1
Secretary of War	6
State Department	4
Surgeon General's Office	38
Survey of North American Lakes	1
Topographical Bureau	1
United States Coast Survey	51
General Land Office	6
United States Naval Observatory	101
United States Patent Office	149
War Department	2
Washington Public Schools	6
Colonel H. L. Abbott	1
F. L. Apel	1
Professor S. F. Baird	18
Hon. Henry Barnard	2
WATERVILLE, MAINE.	
Waterville College	1
WORCESTER, MASSACHUSETTS.	
American Antiquarian Society	11

Total addresses of institutions	238	
Total addresses of individuals	263	
		501
Total number of parcels to institutions	3,245	
Total number of parcels to individuals	885	
		4,130

LIST OF METEOROLOGICAL STATIONS AND OBSERVERS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR 1869.

B. signifies barometer; P. psychrometer; T. thermometer; R. rain gauge; A. all four instruments; N. no instrument.

Station.	Name of observer.	North latitude.	West longitude.	Height.	Instruments.	No. months received.
		° ' "	° ' "	Feet.		
BRITISH AMERICA.						
St. John, Newfoundland	Caswell, Rev. R. C.	47 33	52 43	120	B. T.	1
Stanbridge, Quebec, Canada	Gilmour, A. H. J.	45 8	73	222	T.	12
Wolfville, (Acadia College,) Nova Scotia.	Higgins, Prof. D. F.	45 6	64 25	80	A.	10
Clifton, Ontario, Canada	Jones, W. Martin				T.	12
Abitibi Post, Hudson Bay Territory.	Lockhart, James				T.	5
St. John, New Brunswick	Murdock, G.	45 16 42	66 3 45	135	A.	12
Winnipeg, Assiniboin	Stewart, James	49 52	97	650	A.	9
MEXICO.						
Mirador, Vera Cruz	Sartorius, Dr. Charles	19 14 40	96 25	3,600	A.	12
BERMUDA.						
Center Signal Station, St. Georges	Royal Engineers, (in the Royal Gazette.)				A.	12
ALABAMA.						
Carlowville, Dallas Co	Alison, H. L., M. D.	32 10	87 15	300	T. R.	12
Near Havana, Hale Co	Jennings, S. K., M. D.	32 30	87 41	500	P. T. R.	11
Moulton, Lawrence Co	Peters, Thomas M	34 27	85 25	643	B. T. R.	12
Opilika, Lee Co	Shields, Miss Ella B.				T. R.	9
Mobile, Mobile Co	Taylor, L. B.	30 41 34	88 10	14	T. R.	5
Greene Springs School, Hale Co.	Tutwiler, Prof. H	32 50	87 46	500	T. R.	10
Fish River, Baldwin Co	Vankirk, W. J				T. R.	6
ALASKA.						
Sitka	Bryant, Charles	57 2 51	135 16 15	10	B. T. R.	2
ARKANSAS.						
Helena, Phillips Co	Russell, O. F.	34 32 52	90 8 46		T.	5
CALIFORNIA.						
Monterey, Monterey Co	Canfield, Dr. C. A.	36 36	121 52	34	A.	12
Chico, Butte Co	Cheney, Dr. W. F.	39 44 45	121 44 37	150	T. R.	2
Watsonville, Santa Cruz Co	Compton, Dr. A. J.	36 56	121 46 40	45	T. R.	10
Murphy's, Calaveras Co	Cutting, Ephraim	38 10	120 30	2,201	T. R.	3
Mare Island	Naval Hospital	38 6 19	122 15 19	29½	B. T. R.	12
Vacaville, Solano Co	Simmons, Prof. J. C.	38 21 21	121 58 23	175	B. T. R.	12
Stony Point, Sonoma Co	Thornton, Dr	38 40	122 50	500	T. R.	3
Paradise City, Stanislaus Co	Wright, J. W. A.	37 30	120 55	125	P. T. R.	2
COLORADO TERRITORY.						
Denver, Arapahoe Co	Byers, William N., and S. Y. Sopris.	39 47	105 5	5,350	R.	1
Cañon City, Fremont Co	Macon, Thomas	38 30	105	4,700	R.	1
CONNECTICUT.						
Pomfret, Windham Co	Hunt, Rev. Daniel	41 52 30	72 20	587	A.	3
Middletown, Middlesex Co	Johnson, Prof. John	41 33	72 39	205	A.	11
Colebrook, Litchfield Co	Rockwell, Miss C	42	73 3	1,210	T. R.	12
Brookfield, Fairfield Co	Roe, Rev. Sanford W.	42 27	73 33	100	T. R.	10
Waterbury, New Haven Co	Williams, Rev. R. G.	41 33	73 2		B. T. R.	8
Columbia, Tolland Co	Yeomans, William G.	41 40	72 42		T. R.	12
DELAWARE.						
Milford, Kent Co	Whittier, Mrs. A. C.	38 55	75 30		T. R.	7
FLORIDA.						
Jacksonville, Duval Co	Baldwin Dr. A. S.	30 15	82	20	A.	12
Ocala, Marion Co	Barker, Edward				T.	12
Manatee, Manatee Co	Coachman, B. A	27 30	82 45	6	T. R.	12

List of meteorological stations and observers, &c., for the year 1869.—Continued.

Station.	Name of observer.	North latitude.	West longitude.	Height.	Instruments.	No. months received.
FLORIDA—Continued.		° ′ ″	° ′ ″	Feet.		
Pilatka, Putnam Co	Fiske, W. M. L				A.	3
Port Orange, Volusia Co	Hawks, Dr. J. M., and Mrs.				T.	12
Lake City, Columbia Co	Ives, Edward R	30 10	82 40	184	T. R.	1
Chattahoochie Arsenal, Gadsden Co.	Martin, M	30 48	84 48	180	T. R.	9
Near Pilatka, Putnam Co	Robinson, Gen. Geo. D	29 45	82 20		P. T. R.	7
GEORGIA.						
Macon, Bibb Co	Adams, J. F	32 50	83 37	339	T. R.	5
Atlanta, Fulton Co	Deckner, F., and sons	33 45	84	1,050	T. R.	11
St. Mary's, Camden Co	Hillyer, H. L	30 50	81 40	25	T. R.	7
Macon, Bibb Co	Proctor, Miss S. M	32 50	83 30 30	1,300	A.	3
Penfield, Greene Co	Sanford, Prof. S. P				T. R.	12
Macon, Bibb Co	Whitney, Miss S. J	32 47	83 47	1,300	A.	5
ILLINOIS.						
Elmore, Peoria Co	Adams, W. H				R.	10
Near Tiskilwa, Bureau Co	Aldrich, Verry	41 15	89 15	550	T.	12
Sandwich, De Kalb Co	Ballou, N. E	41 31	88 30	665	A.	12
Elmira, Stark Co	Blanchard, O. A	41 12	90 15		T. R.	9
Andalusia, Rock Island Co	Bowman, E. H	41 25	90 46		B. T.	12
Peoria, Peoria Co	Brendel, Dr. F	40 43	89 30	440	A.	12
Springfield, Sangamon Co	Brinkerhoff, Geo. M	39 48	89 33		T.	12
Chicago, Cook Co	Brookes, Samuel	41	87		T.	12
Alta, Lee Co	Carey, Daniel	41 45	89		T.	12
Louisville, Clay Co	Chase, Dr. D. H	38 40	88 30		T. R.	11
Loammi, Sangamon Co	Dudley, Timothy	39 40	90	680	T. R.	8
Decatur, Macon Co	Dudley, Timothy	39 40	89 10		T. R.	3
Mount Sterling, Brown Co	Duncan, Rev. Alexander	40	91 15		T. R.	12
Golconda, Pope Co	Eldridge, W. V	37 41	88 46		T. R.	12
Pana, Christian Co	Finley, Dr. Thomas	39 24 21	89 6 5	735	T. R.	7
Near South Pass, Union Co	Freeman, H. C			650*	T. R.	9
Manchester, Scott Co	Grant, John, and C. W	39 33	90 14 36		A.	12
Wapella, De Witt Co	Graff, T. Louis	40 11	89 7		N.	12
Mattoon, Coles Co	Henry, W. E	39 29 10		740	T. R.	5
Marengo, McHenry Co	James, J. W	42 13	88 31	780	T. R.	8
Chicago, Cook Co	Langgüth, John G., jr	42	87 30	600	A.	11
Galesburg, Knox Co	Livingston, Prof. W	40 55	90 25		A.	12
Evanston, Cook Co	Marcy, Prof. Oliver	42 1	87 38	570	A.	12
Augusta, Hancock Co	Mead, Dr. S. B	40 10	91		A.	12
Ottawa, La Salle Co	Merwin, Mrs. E. H	41 20	88 47		T. R.	10
Belvidere, Boone Co	Moss, G. B	42 15	88 47		T. R.	12
Near Wyanet, Bureau Co	Phelps, E. S., and Miss L. E.	41 30	89 45		T. R.	11
Marengo, McHenry Co	Rogers, O. P., and F	42 14	88 38	842	B. T. R.	3
King's Mills, Kane Co	Spaulding, Dr. A., and Mrs.	41 45	88 22	696	A.	9
Dubois, Washington Co	Spencer, W. C	38 14	89 16	405	T. R.	12
Waterloo, Monroe Co	Sum, Francis	38 30	90 20		T. R.	5
Winnebago Depot, Winnebago Co.	Tolman, J. W., and Miss.	42 17	89 12	900	B. T. R.	12
Effingham, Effingham Co	Thompson, Dr. W	39 3	88 5	592	T. R.	4
Warsaw, Hancock Co	Whitaker, B	40 20	91 31		T. R.	12
INDIANA.						
Near Laporte, Laporte Co	Andrew, Fred. G			184*	T. R.	6
Mount Carmel, Franklin Co	Applegate, J. A. and daughter.	39 22	84 51	900*	T. R.	8
Valparaiso, Porter Co	Beer, Rev. Robert	41 29	87 6		R.	2
Vevay, Switzerland Co	Boerner, Charles G	38 46	84 59 20.5	525	A.	12
New Harmony, Posey Co	Chappelsmith, John	38 08	87 50	350	A.	12
Laconia, Harrison Co	Crosier, A	37 47	85 50		T. R.	6
New Albany, Floyd Co	Crosier, Dr. E. S	38 02	85 32	553	B. T. R.	2
Spiceland, Henry Co	Dawson, William	39 48	85 18	1,025	B. T. R.	10
Knightstown, Rush Co	Deem, D	39 46	85 24	800	A.	12
Bloomington, Monroe Co	Dodd, Prof. C. M	39 15	86 28	771	A.	10
Merom, Sullivan Co	Holmes, Thomas	39 5	87 40		T. R.	12
Jalapa, Grant Co	Irwin, A. C	40 40	85 43		T. R.	5
Muncie, Delaware Co	Kemper, G. W. H., M. D.	40 12	85 16		T. R.	11
Rensselaer, Jasper Co	Loughridge, J. H	40 56	87 13	725	T. R.	8

* Estimated.

List of meteorological stations and observers, &c., for the year 1869—Continued.

Stations.	Name of observer.	North latitude.	West longitude.	Height.	Instruments.	No. months received.
INDIANA—Continued.		° ′ ″	° ′ ″	Feet.		
Columbia City, Whitley Co	McCoy, Dr. F. and Miss	41 10	85 30	......	T. R.	11
Lafayette, Tippecanoe Co	Newton, J. W	....	....	......	B. T. R.	8
Cannelton, Perry Co	Smith, Palmer	37 57	86 41 30	367	B. T. R.	2
Kentland, Newton Co	Spitler, Daniel	40 56	87 12	725	T. R.	8
Aurora, Dearborn Co	Sutton, George	39 5 54	84 54	509	A.	12
Harveysburg, Fountain Co	Williams, Mrs. Dr. B. C	39 55	87 40	......	T. R.	10
Indianapolis, Marion Co	Woolen, Dr. G. V	39 47	87 6	698	A.	12
IOWA.						
Boonsboro, Boone Co	Babcock, E	42	93 14	1,160	T. R.	7
Lizard P. O., Pocahontas Co	Bruce, J. J	42 30	94 25	......	T. R.	1
Vawter's Grove, Adair Co	Bryant, A. F	41 20	94 30	1,500	T. R.	12
Mount Vernon, Linn Co	Collin, Prof. Alonzo	42	91 30	......	T.	12
Guttenberg, Clayton Co	Dickinson, James P	43	90 50	690	T.	12
Near Algona, Kossuth Co	Dorweiler, P	43	94 26	1,500	T.	12
Near Newton, Jasper Co	Failor, A	42	94	......	T. R.	5
Clinton, Clinton Co	Farnsworth, P. J	41 47	90 10	630	T. R.	12
Dubuque, Dubuque Co	Horr, Dr. A. and E. W	42 30	90 39 51	666	A.	12
Waukon, Alamakee Co	Hancock, E. M	....	....	......	T. R.	9
Fort Dodge, Webster Co	Jorgenson, C. N	42 30	94	......	T. R.	3
West Union, Fayette Co	McClintock, F	42 58	91 50	1,300*	B. T.	5
Near Fort Madison, Lee Co	McCready, Daniel	40 37	91 28	......	T. R.	12
Grant City, Sac Co	Miller, E., and Mrs. R	42 16	94 57 36	......	T. R.	12
Monticello, Jones Co	Moulton, M. M	42 15	91 15	800	T. R.	12
Iowa City, Johnson Co	Parvin, Prof. Thomas S	41 36 53	91 30 10	......	A.	12
Davenport, Scott Co	Sheldon, Prof. D. S	40 31	90 40	737	A.	8
Waterloo, Black Hawk Co	Steed, D	42 30	92 30	......	T.	12
Harris Grove, Harrison Co	Stern, Jacob F	41	95	928	T. R.	12
Near Rolfe, Pocahontas Co	Strong, Oscar I	42 50	94 34	1,000*	T. R.	11
Mineral Ridge, Boone Co	Sullivan, J. T	42 6	93 40	1,200*	T. R.	7
Spring Grove, Hardin Co	Townsend, N	43 32	93 20	......	T. R.	9
Muscatine, Muscatine Co	Walton, J. P	41 25	91 2	582	A.	3
The Woodlands, Floyd Co	Wadey, H	43	93	......	T.	12
Independence, Buchanan Co	Warne, Dr. George	42 25	92 6	940	B. T. R.	12
Algona, Kossuth Co	Warren, James H	43 5	94 15	......	T.	12
Byron Township, Buchanan Co	Wheaton, Mrs. D. B	42 29 25	91 50 8	......	T. R.	10
Whitesboro, Harrison Co	Witter, D. K. and Miss M. E	41 38	95 40	......	T. R.	10
Vinton, Benton Co	Wood, James	42 15	92 45	607*	T. R.	9
Bowen's Prairie, Jones Co	Woodworth, S	42 15	....	800	B. T. R.	12
KANSAS.						
Olathe, Johnson Co	Beckwith, W	38 50	94 30	......	T. R.	11
Near Ames, Story Co	Cotton, John M	42	93 30	790	T. R.	1
Burlington, Coffey Co	Crocker, Allen	38 8	95 27	825	R.	11
Crawfordsville, Crawford Co	Daniels, Percy	37 53	84 55	......	T. R.	6
Neosho Falls, Woodson Co	Groesbeck, Mrs. E. W	37	90	......	T. R.	9
Atchison, Atchison Co	Horn, Dr. H. B. and Miss C.	39 42	95	1,000	T. R.	12
Baxter Springs, Cherokee Co	Ingraham and Hyland	37 3	94 37	......	T. R.	12
Manhattan, Riley Co	Mudge, Prof. B. F	39 12	96 40	1,300	B. T. R.	12
Near Leroy, Coffey Co	Shoemaker, J. G	38 6 28	95 27 39	......	B. T. R.	12
Lawrence, Douglas Co	Snow, Prof. F. H	38 55	95 15	850	A.	12
Leavenworth, Leavenworth Co	Stayman, Dr. J	39 20	94 33	787	T. R.	12
Near Paoli, Miami Co	Walrad, L. D	38 30	95 30	......	T. R.	8
Holton, Jackson Co	Walters, Dr. James	39 27	95 10	1,172	T.	12
Council Grove, Morris Co	Woodworth, Dr. A	38 40	96 30	......	T. R.	11
KENTUCKY.						
Danville, Boyle Co	Beatty, O	37 40	84 30	900?	B. T. R.	9
Clinton, Hickman Co	Cleland, T. H	36 40	89 10	......	T. R.	7
Louisville, Jefferson Co	Manly, Dr. Samuel D	....	....	......	A.	4
Pine Grove, Clark Co	Martin, Dr. Samuel D	38 4	....	978	A.	12
Arcadia, Lincoln Co	Shriver, Howard	37 34	84 30	900*	A.	3
Lexington, Fayette Co	Williams, N	38 6	84 18	950	A.	2
Lexington, Fayette Co	Williams, S. R	38 6	84 18	950	A.	2
Springdale, (near Louisville,) Jefferson Co.	Young, Mrs. L	38 6 55	85 24 13	570	A.	10

* Estimated.

List of meteorological stations and observers, &c., for the year 1869—**Continued.**

Station.	Name of observer.	North latitude.	West longitude.	Height.	Instruments.	No. months received.
LOUISIANA.		° ′ ″	° ′ ″	*Feet.*		
Benton, Bossier Parish	Carter, J. H	32 30	93 45	......	T.	6
New Orleans, Orleans Parish	Foster, R. W	......	......	......	B. T.	12
Shreveport, Caddo Parish	Leavenworth, F. P	32 31	93 45	237	R.	4
MAINE.						
Houlton, Aroostook Co	Fernald, C. H	46 7	67 49 24	470	T. R.	12
Gardiner, Kennebec Co	Gardiner, R. H	44 53	69 45 50	......	A.	12
Cornish, York Co	Guptill, G. W	43 40	70 44	800	T. R.	12
Lisbon, Androscoggin Co	Moore, Asa P	44	70 4	130	T. R.	12
Standish, Cumberland Co	Moulton, John P	43 45	70 30	280	T. R.	8
Steuben, Washington Co	Parker, J. D	44 31 21	67 57 34	50†	T. R.	12
Rumford Point, Oxford Co	Pettingill, W	44 30	70 40	600	T. R.	2
Williamsburg, Piscataquis Co	Pitman, Edwin	45 21	69 71	......	T. R.	11
Oxford, Oxford Co	Smith, Howard D	44 8	70 33	......	T. R.	12
Cornish, York Co	West, Silas	43 33	70 50	784	B. T. R.	11
West Waterville, Kennebec Co	Wilbur, B. F	44 30	69 46	......	T. R.	12
MARYLAND.						
Annapolis, Anne Arundel Co	Goodman, William R	38 58	76 29	20	A.	12
Frederick, Frederick Co	Hanshew, John K	39 24	77 26 30	......	B. T. R.	5
Emmittsburg, Frederick Co	Jourdan, Prof. C. H	39 40	77 20	......	A.	12
Woodlawn, Cecil Co	McCormick, James O	39 38	76 4	......	B. T. R.	12
Emmittsburg, Frederick Co	Smith, Eli	39 43 15	77 26 45	498	T.	4
St. Mary's City, St. Mary's Co	Stephenson, Rev. J	38 10	76 30	45	T. R.	9
MASSACHUSETTS.						
Richmond, Berkshire Co	Bacon, William	42 23	73 20	1,000	T. R.	0
West Newton, Middlesex Co	Bixby, John H	42 21	71 17	55†	T. R.	11
Newbury, Essex Co	Caldwell, John H	42 45	70 55	25	T.	5
Lunenburg, Worcester Co	Cunningham, George A	42 35	71 43	450	B. T. R.	12
Hinsdale, Berkshire Co	Dewhurst, Rev. E	43 27	73 7	......	B. T. R.	12
Worcester, Worcester Co	Draper, Joseph, M. D	42 16 17	71 48 13	528	A.	12
Lawrence, Essex Co	Fallon, John	42 42 13	71 10 13	143	A.	7
Williamstown, Berkshire Co	Hopkins, Prof. A	42 42 37	73 12 42	686	B. T. R.	11
Topsfield, Essex Co	Merriam, Sidney A	42 38	70 57	......	A.	11
Mendon, Worcester Co	Metcalf, J. G	42 6 23.23	71 33 35.97	......	B. T. R.	12
North Billerica, Middlesex Co	Nason, Rev. Elias	42 35 9	70 16 30	20*	B. T.	12
Kingston, Plymouth Co	Newcomb, Guilford S	42	70 45	60	T. R.	12
Georgetown, Essex Co	Nelson, S. Augustus,	42 42	71	......	T. R.	6
Cambridge, Middlesex Co	Perry, Rev. J. B., and Mrs.	42 20	71 11	40	T.	12
New Bedford, Bristol Co	Rodman, Samuel	41 39	70 56	90	A.	10
Amherst, Hampshire Co	Snell, Prof. E. S	42 22 17	72 34 30	267	A.	12
Milton, Norfolk Co	Teele, Rev. A. K	42 14 37.30	71 6 2.30	115	B. T. R.	12
MICHIGAN.						
Old Mission, Grand Traverse Co.	Avery, C. P	44 65	85 30	640	T. R.	6
Litchfield, Litchfield Co	Bullard, R	42 0 45	84 46 10	1,040	B. T. R.	12
Otsego, Allegan Co	Chase, Dr. Milton	......	......	......	T.	12
Ontonagon, Ontonagon Co	Ellis, Dr. Edwin	46 52	89 30	620	T.	11
Pennsylvania Mine, Kewenaw Co.	Griffith, Richard H	......	......	......	B. T. R.	5
Grand Rapids, Kent Co	Holmes, Dr. E. S	43	85 40	780	T.	12
Lansing, Ingham Co	Kedzie, Prof. R. C	......	......	......	A.	12
Oshtemo, Kalamazoo Co	Mapes, H. H	......	......	......	N.	12
Pleasanton, Manistee Co	Millard, Joseph D	44 25	86 10	750	T. R.	12
Muskegon, Muskegon Co	Pattison, H. A	......	......	......	B. T. R.	11
Sugar Island, Alpena Co	Paxton, J. W	45 2 12	83 5 40	574	B. T. R.	11
Coldwater, Branch Co	Southworth, N. L	......	......	......	T. R.	12
Homestead, Benzie Co	Steele, George E	44 35	86 30	......	T.	4
Holland, Ottawa Co	Streng, L. H	42 42	86	......	T. R.	2
North Port, Leelanaw Co	Smith, Rev. George N	45 8	85 41	592	T. R.	12
Monroe, Monroe Co	Whelpley, Miss Helen I	41 58	83 23	590	T. R.	12
Central Mine, Keweenaw Co	Whittlesey, S. H	47	87 54	1,177	T. R.	12
MINNESOTA.						
Afton, Washington Co	Babcock, Dr., & Mrs. B. F	44 50	93	950	T. R.	12
Sauk Centre, Stearns Co	Bloomfield, Smith	45 53 55	95 22 2	1,225†	T. R.	1
Minneapolis, Hennepin Co	Cheney, William	44 48	93 10	856	A.	11

* Above Concord River. † Estimated.

List of meteorological stations and observers, &c., for the year 1869—Continued.

Station.	Name of observer.	North latitude.	West longitude.	Height.	Instruments.	No. months received.
MINNESOTA—Continued.		° ′ ″	° ′ ″	Feet.		
St. Cloud, Stearns Co	Garrison, O. E	45 36	94 6	......	T. R.	1
Rochester, Olmsted Co	Milmine, Alfred	44	92 26	......	R.	3
Madelia, Watonwa Co	Murphy, W. W	44	94 30	......	T. R.	11
Saint Paul, Ramsey Co	Paterson, Rev. A. B	44 54 46	94 4 54	800	T. R.	12
White Earth Reservat'n, Becker Co.	Pyle, Dr. D	47 50	95	......	T. R.	4
New Ulm, Brown Co	Roos, Charles	44 16	94 26	821	T. R.	12
Beaver Bay, Lake Co	Wieland, C	47 12	96 19	657	T. R.	12
Sibley, Sibley Co	Woodbury, C. W., & C. E.	44 31	94 25	......	T. R.	12
Koniska, McLeod Co	Young, Thomas M	45 10	94 20	......	T. R.	11
MISSISSIPPI.						
Marion, Lauderdale Co	Florer, T. W	32 25	88 5	83	T. R.	12
Columbus, Lowndes Co	Lull, James S	35 30	88 29	227	T. R.	12
Near Brookhaven, Lawrence Co	Keenan, T. J. R	31 34	90 40	......	T. R.	12
Natchez, Adams Co	McCary, W	31 34	91 24 42	......	B. T. R.	12
Grenada, Yalabusha Co	Moore, Albert	33 45	90	......	T. R.	12
Brookhaven, Lawrence Co	Moore, Thomas B	31 37	90 15	430	T. R.	2
Near Paulding, Jasper Co	Robinson, Rev. E. S	32 10	89 10	215	A.	3
MISSOURI.						
St. Joseph, Buchanan Co	Bullard, Rev. H	39 45	94 53	......	T. R.	11
Harrisonville, Cass Co	Christian, John	......	......	......	T. R.	12
Jefferson City, Cole Co	De Wegl, N	38 20	92	650	B. T.	12
Allentown, St. Louis Co	Fendler, A	38 29	90 45	482	A.	12
Oregon, Holt Co	Kancher, W	39 58 40	95 10	1,100	A.	12
East Prairie, Mississippi Co	Miller, A	36 55	......	......	T. R.	1
Hermitage, Hickory Co	Moore, Dr. W	37 56	93 16	......	T. R.	12
Warrensburg, Johnson Co	Pollock, Rev. J. E	38 45	93 40	600	T. R.	8
Bolivar, Polk	Race, J. A	37 30	93 20	1,000	T. R.	12
Near Rolla, Phelps	Ruggles, Homer	37 38	91 33	......	T. R.	12
Hematite, Jefferson Co	Smith, John M	38 11	90 37	475	T. R.	11
St. Louis, St. Louis Co	Stuntebeck, Rev. F. H., and Rev. I. Straetmans.	38 37 28	90 15	470	A.	11
Keytesville, Chariton Co	Veatch, Charles	......	......	......	B. T. R.	5
MONTANA.						
Benton City, Chouteau Co	Clevenger, Dr. S. V	......	......	......	T. R.	4
Deer Lodge City, Deer Lodge Co.	Stuart, Granville	46 40*	112 40*	4,240	T. R.	12
NEBRASKA.						
Richland, Washington Co	Bowen, John S	41 22	96 12	1,350*	T.	12
Dakota City, Dakota Co	Brown, H. H	40 30	96 30	......	T.	8
Near Bellevue, Sarpy Co	Caldwell, Mrs. E. E	41 8	95 46	......	T. R.	12
Decatur, Burt Co	Case, Dr. G. C	42	95 30*	......	T. R.	5
Glendale, Cass Co	Child, Dr. A. L., and Miss J. E.	40 55	96 05	1,010	T. R.	10
Fontanelle, Washington Co	Gibson, H	......	......	......	T. R.	9
Blackbird Hills, Burt Co	Hamilton, Rev. W	42 10	96	......	T. R.	11
Peru, Nemaha Co	McKenzie, J. M	40	95 45	1,000*	T.	4
Nebraska City, Otoe Co	Pettinger, J. M	40 42	95 45	1,225	T. R.	1
De Soto, Washington Co	Seltz, Charles	41 50	96	975	T. R.	12
Nebraska City, Otoe Co	Zalaner, P	40 42	95 45	1,225	T. R.	11
NEW HAMPSHIRE.						
Tamworth, Carroll Co	Brewster, A	43 48	71 18	......	T. R.	3
Stratford, Coos Co	Brown, B	44 40	71 7	1,000	T. R.	12
Dunbarton, Merrimack Co	Colby, A	43 6	71 35	730	T. R.	11
South Antrim, Hillsboro' Co	Hurlin, Rev. William	......	......	......	N.	9
Whitefield, Coos Co	Kidder, L. D	44 20	71 15	......	T. R.	7
Shelburne, Coos Co	Odell, F	44 23	71 6	700	B. T.	7
North Barnstead, Belknap	Pitman, Charles H	43 38	71 27	......	T. R.	8
Concord, Merrimack	Wheeler, J. T	43 12	71 29	550	T.	1
NEW JERSEY.						
Chester Township, Burlington Co	Beans, Thomas J	39 59	74 54	......	T. R.	12
Haddonfield, Camden Co	Boadle, J., and J. L. Lippincott.	......	......	......	A.	10

* Estimated.

List of meteorological stations and observers, &c., for the year 1869—Continued.

Station.	Name of observer.	North latitude.	West longitude.	Height.	Instruments.	No. months received.
New Jersey—Continued.		° ′ ″	° ′ ″	*Feet.*		
Paterson, Passaic Co	Brooks, William	40 55	74 10	60*	T. R.	12
Trenton, Mercer Co.	Cook, Ephriam R	40 14	74 46 30	60	B. T. R.	11
Newfield, Gloucester Co	Couch, E. D	39 30	74 50	180	T.	12
Readington, Hunterdon Co	Fleming, John				T.	5
Mechanicsville, Hunterdon Co	Fleming, John, and W. T. Herr.				T.	2
New Brunswick, Middlesex Co	Hasbrouck, I. E	40 30	74 27	80	A.	6
Vineland, Cumberland Co	Ingram, Dr. J				A.	12
New Germantown, Hunterdon Co	Noll, A. B	42 40	74 45		B. T. R.	11
Rio Grande, Cape May Co	Palmer, Miss J. R	39 16	74 42		T. R.	11
Newton, Sussex Co	Ryerson, Dr. Thomas	41 2 45	74 40 12	659.5	A.	7
Greenwich, Cumberland Co	Sheppard, Miss R. C	39 20	75 25	30	A.	12
Dover, Morris Co	Shriver, Howard	40 54	74 35	652	A.	2
Newark, Essex Co	Whitehead, W. A	40 45	74 10	35	B. T. R.	12
New York.						
Ardenia Philipstown, Putnam Co	Arden, Thomas B	40 20 22	73 53 22	180	T. R.	11
Milo, Yates Co	Baker, Gilbert D	42 30		868	B. T. R.	7
South Trenton, Oneida Co	Barrows, Captain Storrs	43 10	74 56	835	T. R.	12
Palermo, Oswego Co	Bartlett, E. B	43 26	77 26	327	T. R.	12
Minaville, Montgomery Co	Bussing, John W	42 54	74 15		T. R.	12
Fort Edward, Washington Co	Cooley, Prof. James S	43 13	73 42		B. T. R.	3
Nyack, Rockland	De la Verny, C	41 4 35	73 59 58	124	A.	5
Little Genesee, Allegany Co	Edwards, Daniel	42 0 15	78 20	1,500	B. T. R.	12
Newburg, Orange Co	Gardiner, J. H	41 30 53	74 1	96	B. T. R.	9
Near Depauville, Jefferson Co	Haas, H	44 10	76 3	350	T. R.	12
Hudson, Columbia Co	Hachenberg, Dr. G. P	42 14	73 46		P. T. R.	7
Near Kingston, on the Hudson, Ulster Co	Hendricks, D. B	41 50	74 2	150	T. R.	6
Nichols, Tioga Co	Howell, Robert	42	76 32		T.	12
South Hartford, Washington Co	Ingalsbe, G. M	43 18	73 21 3	400	T. R.	11
Buffalo, Erie Co	Ives, William	42 50	78 56	600	B. T. R.	12
Newark Valley, Tioga Co	Johnson, Rev. Samuel				T. R.	12
New York, New York Co	Joy, Prof. C. A	40 43	74 5	100	A.	12
Cooperstown, Otsego Co	Keese, G. Pomeroy	42 50	74 54	1,200*	T. R.	3
Flatbush, Kings Co	Mack, Eli T	40 37 17	74 1 33	54	B. T. R.	12
Oswego, Oswego Co	Malcolm, W. S	43 28	76 30	250	B. T. R.	12
Rochester, Monroe Co	Mathews, H. W	43 08	77 51	525	A.	12
Locust Grove, Lewis Co	Merriam, C. C	43 32 30	75 24		B. T. R.	12
Farmingdale, Queens Co	Merritt, J. C	40 40 40	73 30	102	N.	12
Central Park, New York	Meteorological observ'y	40 45 58	73 57 58	97	A.	12
Throg's Neck, Westchester Co	Morris, Miss E	40 49 15	73 48 45	43½	T.	11
New York, New York Co	Morris, Prof. O. W	40 50 25	73 56 30	165	A.	12
Ludlowville, Tompkins Co	Murphy, C. P	42 33	76 35	600	T.	9
New York, New York Co	Naval Hospital	40 41 30	74 1	56	B. T. R.	12
North Volney, Oswego Co	Partrick, J. M				T.	8
Sloansville, Schoharie Co	Potter, G. W	42 41	74 31		T. R.	4
Germantown, Columbia Co	Roe, Rev. S. W				T.	1
Gouverneur, St. Lawrence Co	Russell, C. H	44 19	75 29		B. T. R.	12
New York, New York Co	Rutgers Female College	40 42	74 1 8	25	A.	2
Brookhaven, Suffolk Co	Smith, E. A., and daughters.	40 49	72 36	13	T. R.	12
Cazenovia, Madison Co	Soule, Prof. William	42 55	75 46	1,260	B. T.	12
Oneida, Madison Co	Spooner, Dr. S	43 4	75 50	500	T. R.	12
Waterburg, Tompkins Co	Trowbridge, D	42 30	77 15	800*	T.	12
White Plains, Westchester Co	Willis, O. R	41 5	73 40	273	T.	11
N. Hammond, St. Lawrence Co	Wooster, C. A	44 30	75 41		B. T. R.	12
Houseville, Lewis Co	Yale, Walter D	43 40	75 32		T. R.	11
North Carolina.						
Goldsboro, Wayne Co	Adams, Prof. E. W	35 20	77 51	102	T. R.	12
Near Statesville, Iredell Co	Allison, Thomas P	35 30	80 30		T. R.	10
Asheville, Buncombe Co	Aston, Edward J				T.	12
Raleigh, Wake Co	Brewer, Fisk P	35 47	78 48		T. R.	1
Asheville, Buncombe Co	Hardy, Dr. J. F. E	35 30	80 31	2,250	B. T.	12
Oxford, Granville Co	Hicks, William R	36 23	78 14		T. R.	11
Attaway Hill, Stanly Co	Krom, F. J	35 25	80	850*	T. R.	12
Chapel Hill, Orange Co	Patrick, Prof. D. S				T.	9
Trinity College, Randolph Co.	Pearsall, E. D	36 45	80	900	T. R.	5
Mt. Olive, Wayne Co.	Pearsall, E. D	35 45	78	100	T. R.	3
Kenansville, Duplin Co	Sprunt, Rev. J. M	34 53	75 3	40*	B. T. R.	10

* Estimated.

List of meteorological stations and observers, &c., for the year 1869—Continued.

Station.	Name of observer.	North latitude.	West longitude.	Height.	Instruments.	No. months received.
NORTH CAROLINA—Continued.		° ′ ″	° ′ ″	*Feet.*		
Guilford Mine, Guilford Co	Wray, Alexander	36	80	990	N.	1
Raleigh, Wake Co	Taylor, Miss M. H	35 47	78 46	37	T. R.	5
OHIO.						
New Lisbon, Columbiana Co	Benner, J. F	40 45	80 45	961	B. T. R.	3
Amesville, Athens Co	Brawley, E. H	39	82	......	R.	1
North Fairfield, Huron Co	Burras, O	41 8	82 40	660	A.	11
Near Bowling Green, Wood Co	Clarke, John	41 22	83 40	700*	T. R.	12
Bethel, Clermont Co	Crane, G. W	39	84	555	T. R.	12
Steubenville, Jefferson Co	Doyle, Joseph B	40 45	80 47	......	B. T. R.	11
Little Mountain, Geauga Co	Ferriss, E. J	41 38	81 16	600	A.	11
Westerville, Franklin Co	Haywood, Prof. J	40 4	83	......	A.	12
College Hill, Hamilton Co	Hammitt, John W	39 19	84 14 45	800	T. R.	11
Cincinnati, Hamilton Co	Harper, G. W	39 6	84 29	305†	B. T. R.	7
Springfield, Clark Co	Herron, Rev. J. H	39 53 25	83 49 15	......	T. R.	1
Smithville, Wayne Co	Hoover, William	40 52	81 51	934	T. R.	6
Kelley's Island, Erie Co	Huntingdon, George C	41 35 44	82 42 32	587	A.	12
Cleveland, Cuyahoga Co	Hyde, Gustavus A	41 30	80 40	......	B. T. R.	12
Edgerton, Williams Co	Knight, A. B	41 32	84 45	831	T. R.	2
Ripley, Huron Co	Marsh, Mrs. M. M	41	82 30	965	A.	6
Hillsboro, Highland Co	Mathews, J. McD	39 13	....	......	A.	12
Gilmore, Tuscarawas Co	Moore, Sam'l M	40 18	81 18	1,180	T. R.	11
North Bass Island, Ottawa Co	Morton, Geo. R., M. D	41 36	82 41 53	22‡	T. R.	7
Margaretta Township, Erie Co	Neill, Thomas	41 27	82 46	......	A.	12
Jacksonburg, Butler Co	Owsley, Dr. J. B	39 30	84 17	1,152	T. R.	12
Cincinnati, Hamilton Co	Phillips, R. C	....	....	......	B. T. R.	12
Gallipolis, Gallia Co	Rodgers, A. P	39	82	600	T. R.	8
Martin's Ferry, Belmont Co	Shreve, Miss M. B	40 10	80 48	......	T. R.	4
Kenton, Hardin Co	Smith, Dr. C. H	....	....	543½	T. R.	10
Gambier, Knox Co	Stillwell, C. A., and others.	40 20 30	....	1,000	A.	3
Milnersville, Guernsey Co	Thompson, Rev. D	40 10	81 45	......	T. R.	12
Toledo, Lucas Co	Trembley, Dr. J. B	41 38	83 30	......	B. T. R.	12
Marion, Marion Co	True, Dr. H. A	40 35	83 7	1,077	T. R.	11
North Bend, Hamilton Co	Warder, R. B	39 8	84 35	800	T. R.	1
Mt. Auburn, Hamilton Co	White, Miss A. J., and others.	....	....	1,000	A.	11
Williamsport, Pickaway Co	Wilkinson, J. R	39 37 4	83 7 30	......	T. R.	3
Urbana, Champaign Co	Williams, Prof. M. G	40 6	83 43	1,015	B. T. R.	12
Wooster, Wayne Co	Winger, M	40 48 47	81 55 37	872	T. R.	11
PENNSYLVANIA.						
Avondell, Perry Co	Baker, William E	40 26 40	77 22 50	515	T. R.	4
Tioga, Tioga Co	Bentley, E. T	42	77	1,000	T. R.	11
Silver Spring, Lancaster Co	Bruckhart, H. G	40 51	76 45	......	T.	4
Phœnixville, Chester Co	Coffman, I. Z	40 10	75 26	190	T. R.	6
Carlisle, Cumberland Co	Cook, W. H	....	....	......	B. T. R.	12
Plymouth Meeting, Montgomery Co.	Corson, M. H	40 6	....	......	A.	12
Pocopson, Chester Co	Darlington, F	39 54	75 37	218	T. R.	12
Dyberry, Wayne Co	Day, Theodore	41 36	75 19	......	T. R.	12
Harrisburg, Dauphin Co	Egle, Dr. William H	40 16	76 15	1,400	A.	2
Near Pennsville, Clearfield Co	Fenton, Elisha	41	78 40	......	B. T. R.	12
Blooming Grove, Pike Co	Grathwohl, J	41 30	75	......	T. R.	12
Fallsington, Bucks Co	Hance, Ebenezer	42 12	74 48	30	B. T. R.	12
Harrisburg, Dauphin Co	Heiseley, Dr. J	40 16	76 15	......	A.	7
Mount Joy, Lancaster Co	Hoffer, Dr. J. R. and U. E	40 8	76 32	......	B. T.	12
Brownsville, Fayette Co	Hubbs, Dr. J. Allen	40	80	......	T.	2
Lewisburg, Union Co	James, Professor C. S	40 58	76 58	......	A.	12
Philadelphia, Philadelphia Co	Kirkpatrick, Prof. J. A	39 57 30	75 11 15	60	A.	12
Whitehall, Lehigh Co	Kohler, E	40 44	75 28	450*	T.	12
Newcastle, Lawrence Co	McConnell, E. M	40	80 12	......	T.	12
Westchester, Chester Co	Martin, Dr. George	39 57 31.3	75 36 3	460	A.	11
Germantown, Philadelphia Co	Meehan, Thomas	....	....	......	T.	12
Williamsport, Lycoming Co	Moyer, H. C	41 19	77 30	533	B. T.	4
Philadelphia, Philadelphia Co	Naval Hospital	39 56	75 10	36	B. T. R.	12
Johnstown, Cambria Co	Peelor, David	....	....	1,200	A.	12
Reading, Berks Co	Raser, John Heyl	40 20	75 57	......	T. R.	12
Abington, Luzerne Co	Sisson, Rodman	41 30	75 45	......	T. R.	11
Canonsburg, Washington Co	Smith, Rev. Dr. William	40 16 41	80 10	850	B. T. R.	12
Mooreland, Montgomery Co	Spencer, Miss Anna	40	75 11	250	A.	12
Ephrata, Lancaster Co	Spera, William H	40 12	76 15	......	T. R.	12

* Estimate. † Above Ohio River. ‡ Above Lake Erie.

List of meteorological stations and observers, &c., for the year 1869.—Continued.

Station.	Name of observer.	North latitude.	West longitude.	Height.	Instruments.	No. months received.
PENNSYLVANIA—Continued.		° ′ ″	° ′ ″	*Feet.*		
Salem, Wayne Co	Stocker, J. D	41 30	78 30	......	T. R.	9
Near Connellsville, Fayette Co	Taylor, John	40	79 36	......	T. R.	10
Beaver, Beaver Co	Taylor, Rev. R. T	40 43	80 23	......	T. R.	12
Franklin, Venango Co	Tolman, Rev. M. A	41 24	79 51	980	T. R.	12
Germantown, Philadelphia Co	Turner, Ernest, C. E	....	....	......	B. T. R.	2
Fountain Dale, Adams Co	Walker, S. C	39 44	77 18	......	P. T. R.	12
RHODE ISLAND.						
Newport, Newport Co	Crandall, W. H	41 28 22	71 21 14	25	T. R.	12
SOUTH CAROLINA.						
Aiken, Barnwell Co	Cornish, Rev. John H	33 32	81 34	565	B. T. R.	11
Evergreen, Anderson Co	Earle, E. S	34 30	82 50	......	R.	11
Camden, Kershaw Co	Macrae, Colin	34 17	80 33	240	T. R.	4
Aiken, Barnwell Co	Percival, Dr. W. F	33 32	81 34	565	P. T. R.	2
Wilkinsville, Union Co	Petty, Charles	34 50	81 36	600*	T. R.	12
Fort Hill, York Co	Springs, R. A., jr	35	81	......	T.	1
TENNESSEE.						
Lookout Mountain Educational Institute, Hamilton Co.	Bancroft, Rev. C. F. P	35	81 5	2,200	B. T.	11
Austin, Wilson Co	Calhoun, P. B	....	....	......	T. R.	6
Greenville, Green Co	Doak, S. S. & W. S	36 5	82 51	......	T. R.	12
Memphis, Shelby Co	Goldsmith, E	35 8	90	262	A.	12
Trenton, Gibson Co	Grigsby, William T	36	89	......	T. R.	11
Elizabethton, Carter Co	Lewis, Charles H	36 25	82 15	1,500	T. R.	12
Knoxville, Knox Co	Payne, Prof. J. K	36	84	990	A.	3
Clarksville, Montgomery Co	Stewart, William M	36 29	87 13	481	A.	12
TEXAS.						
Houston, Harris Co	Baxter, Miss E	29 50	95 30	50	T.	5
Galveston, Galveston Co	Beazley, Dr. A. H	29 18	96 6	30	A.	1
Cedar Grove Plantation, Brazoria Co.	Bostwick, J. B	29 10	95 56	60	B. T. R.	5
Palestine, Anderson Co	Brooks, N. S	31 40	95 35	480	T. R.	3
Near Dallas, Dallas Co	Coit, John T	32 53	96 45	......	R.	1
Bellona, Falls Co	Combs, Burke	....	....	......	R.	9
Near Gilmer, Upshur Co	Glaser, J. M	32 46	94 51	950	T. R.	12
Lavaca, Calhoun Co	Heaton, L. D	28 30†	96 40†	17	T. R.	12
Waco, McLennan Co	Merrill, Dr. E	31 35	96 50	......	T. R.	11
Austin, Travis Co	Van Nostrand, J	30 29	97 46	650	P. T. R.	12
Mine Creek, Burleson Co	Wade, F. S	30 25	97 26	600	T. R.	12
Yorktown, De Witt Co	White, Dr. A. C	29	97 37	......	T. R.	10
Lockhart, Caldwell Co	Woodruff, L	....	....	......	T. R.	3
UTAH.						
Coalville, Summit Co	Bullock, Thomas	....	....	......	T.	7
Wanship, Summit Co	Bullock, Thomas	40 42	111	......	T.	4
Harrisburg, Washington Co	Lewis, James	....	....	......	R.	12
St. George, Washington Co	Pearce, H	37 11	114	......	R.	6
Salt Lake City, Salt Lake Co	Phelps, W. W	40 45	111 26	......	T. R.	5
VERMONT.						
Panton, Addison Co	Barto, D. C. & M. E	44	74	......	T. R.	8
Brandon, Rutland Co	Buckland, H	43 45	73	400	T. R.	5
Newport, Orleans Co	Currier, J. M	44 55	72 20	750	T. R.	1
Lunenburg, Essex Co	Cutting, H. A	44 28	71 41	1,124	A.	12
Woodstock, Windsor Co	Doten, H., & L. A. Miller	43 36	72 35	698	T. R.	12
Barnet, Caledonia Co	Eaton, Dr. B. F	44 18	72 5	952	B. T. R.	5
Hartford, Windsor Co	Eaton, Dr. B. F	43 44	72 20	381	B. T.	1
Randolph, Orange Co	Paine, C. S	43 55	72 36	650	T. R.	12
Middlebury, Addison Co	Sheldon, H. A	43 59	73 10	398	A.	12
Craftsbury, Orleans Co	Wild, Rev. E. P	44 40	72 30	1,100	T. R.	12
Castleton, Rutland Co	Williams, Rev. R. G	....	....	......	B. T. R.	4
Charlotte, Chittenden Co	Wing, Miss M. E	....	....	......	T. R.	12

* Estimated. † Approximate.

List of meteorological stations and observers, &c., for the year 1869—Continued.

Station.	Name of observer.	North latitude.	West longitude.	Height.	Instruments.	No. months received.
VIRGINIA.		° ′ ″	° ′ ″	Feet.		
Mulberry Hill, Isle of Wight Co.	Binford, R.	36 50	76 50	100	T. R.	12
Wytheville, Wythe Co	Brown, Rev. J. A	36 55	81 4	2,400	B. T. R.	12
Mount Solon, Augusta Co	Clarke, Dr. J. T., & Miss B.	38 17	79 3	......	T. R.	4
Staunton, Augusta Co	Covell, J. C.	38 8	78 46	1,261	A.	12
Cottage Home, Surrey Co	Jones, Benjamin W	37 10	76 46	......	T.	12
Mechanicsville, Fauquier Co	Martin, William A	38 50	78	......	T. R.	2
Near Lynchburg, Bedford Co	Meriwether, Charles I	37 18	79 19	800*	T.	12
Prospect Hill, Northampton Co.	Moore, C. R	37 22	75 46	40*	B. T. R.	12
Norfolk, Norfolk Co	Naval Hospital	36 25	76 25	25	B. T. R.	12
Near Lexington, Rockbridge Co.	Ruffner, W. H	37 46	79 22	1,000	T. R.	11
Hampton, Elizabeth City Co	Sherman, J. M	37 5	76 20	5	T. R.	12
Wytheville, Wythe Co	Shriver, Howard	36 51	81 3	......	A.	5
Ashland, Hanover Co	Smith, Prof. R. M	37 35 23	77 29 59	221	B. T. R.	1
Snowville, Pulaski Co	Stalnaker, J. W	37	80	1,800*	T. R.	12
Powhatan Hill, King George Co.	Tayloe, Edw. T	....	....	60	T. R.	12
Near Piedmont, Fauquier Co	Williams, Franklin	38 50	78	900*	T. R.	2
Near Vienna, Fairfax Co	Williams, H. C., & Miss L. R. Thrift.	38 53	77 12	400	T. R.	5
WASHINGTON TERRITORY.						
Tatoosh Island Light-house, Clallam Co.	Sampson, Alexander M	....	....	......	T. R.	8
Walla-Walla, Walla-Walla Co	Simmons, A. H	46 5	118 52	930	T. R.	2
WEST VIRGINIA.						
Huttonsville, Randolph Co	Hill, Jacob I	38 45	79 45	1,000	R.	2
Romney, Hampshire Co	McDowell, W. H	....	....	......	T.	7
Ashland, Cabell Co	Roffe, C. L	38 30	82 16	600	T. R.	12
White Day, Mongalia Co	Sharp, Dr. W. H	....	....	......	T.	3
WISCONSIN.						
Embarrass, Waupacca Co	Breed, E. E	41 51	88 37 30	......	T. R.	12
Rocky Run, Columbia Co	Curtiss, W. W	43 26	89 19	......	T. R.	11
Madison, Dane Co	Daniells, Prof. W. W	43 5	39 24	1,068	A.	12
Holland, Sheboygan Co	De Lycer, John	43 36	87 54	670	T.	12
New Lisbon Juneau Co	Dungan, J. L	43 45	90	......	T.	12
Appleton, Outagamie Co	Foye, Prof. J. C	44 10	88 35	800	B. T.	8
Milwaukee, Milwaukee Co	Lapham, Dr. I. A	43 3	87 56 10	604	A.	12
Manitowoc, Manitowoc Co	Lüppe, Jacob.	44 7	87 45	658	B. T. R.	12
Waupacca, Waupacca Co	Mead, H. C	44 20	89 11	900	T.	12
Plymouth, Sheboygan Co	Moeller, G	43 44	88 7	......	B. T. R.	11
Edgerton, Rock Co	Shintz, H. J	42 30	89	1,700	T. R.	12
Bayfield, Bayfield Co	Tate, Andrew	....	....	......	T.	9
Baraboo, Sauk Co	Waite, M. C	43 27 1	89 45 1	920	T. R.	12
Bloomfield, Kenosha Co	Whiting, W. H	....	....	......	T. R.	9

* Estimated.

DEATHS OF OBSERVERS.

Dr. J. Heisely, Harrisburg, Pennsylvania, September 18, 1869.
Rev. Daniel Hunt, Pomfret, Connecticut, July 2, 1869.
Rev. S. R. Williams, Lexington, Kentucky, July —, 1869.

Colleges and other institutions from which meteorological registers were received during the year 1869, *included in the preceding list.*

State.	Institutions.	Location.
Nova Scotia	Acadia College	Wolfville.
Alabama	Greene Springs School	Havana.
Arkansas	Normal School	Helena.
California	Pacific Methodist College	Vacaville.
Connecticut	Collegiate Institute	Waterbury.
	Wesleyan University	Middletown.
Georgia	Mercer University	Penfield.
Illinois	Lombard University	Galesburg.
	Northwestern University	Evanston.
Indiana	City Hospital	Indianapolis.
	Indiana State University	Bloomington.
Iowa	Cornell College	Mount Vernon
	Griswold College	Davenport.
	Iowa State University	Iowa City.
Kansas	Agricultural College	Manhattan.
	State University	Lawrence.
Kentucky	Sayre Institute	Lexington.
Maryland	Mount St. Mary's College	Emmittsburg.
Massachusetts	Amherst College	Amherst.
	State Lunatic Hospital	Worcester.
	Williams College	Williamstown.
Michigan	State Agricultural College	Lansing.
Missouri	St. Louis University	St. Louis.
New Hampshire	St. Paul's School	Concord.
New Jersey	Rutger's College	New Brunswick.
New York	Columbia College	New York.
	Erasmus Hall Academy	Flatbush.
	Institute for Deaf and Dumb	New York.
	Fort Edward Collegiate Institute	Fort Edward.
	Oneida Conference Seminary	Cazenovia.
	Observatory, Central Park	New York.
	Rockland Female Institute	Nyack.
	Rutgers Female College	New York.
North Carolina	Trinity College	Randolph County.
	Goldsboro Female College	Goldsboro.
	University of North Carolina	Chapel Hill.
	Webster Institute	Kenansville.
Ohio	Kenyon College	Gambier.
	Mount Auburn Young Ladies' Institute	Mount Auburn.
	Otterbein University	Westerville.
	Urbana University	Urbana.
	Woodward High School	Cincinnati.
Pennsylvania	Beaver Seminary	Beaver.
	Jefferson College	Cannonsburg.
	Lehigh University	Bethlehem.
	Lewisburg University	Lewisburg.
Tennessee	East Tennessee University	Knoxville.
	Lookout Mountain Educational Inst.	Hamilton County.
	Stewart College	Clarksville.
	Tusculum College	Greenville.
Texas	Institution for Deaf and Dumb	Austin.
Vermont	Normal School	Castleton.
	Woodstock Academy Natural Sciences	Woodstock.
Virginia	Institute for Deaf, Dumb, and Blind	Staunton.
	Randolph Macon College	Ashland.
Wisconsin	Lawrence University	Appleton.
	State University	Madison.

METEOROLOGICAL MATERIAL CONTRIBUTED IN ADDITION TO THE REGULAR OBSERVATIONS DURING THE YEAR 1869.

Académie Impériale des Sciences de St. Petersbourg.—Mémoires. VII Séries, tome xii, No. 4. Untersuchungen über Constitution der Atmosphäre und die Strahlenbrechung in derselben. (2te Abhandlung.) Von Dr. H. Gylden, 1868. 4° 57 pp.

Académie Royale de Belgique.—Observations des phénomènes périodiques pendant les années 1865 et 1866. (Extrait du tome xxxvii des Mémoires.) 4° 74 pp. et 60 pp.

Ackermann, Professor.—Newspapers containing articles on temperature and rainfall of Port au Prince, Hayti.

Australian Horticultural and Agricultural Society.—Horticultural Magazine and Gardeners' and Amateurs' Chronicle. Containing meteorological observations at Yarella, Concord, New South Wales, by A. Stephen.

Baird, Professor S. F.—Newspapers giving accounts of the great storms in New England in September and October, 1869.

Bartlett, E. B.—Review of the weather at Palermo, New York, during the year 1868. (Newspaper slip.)

—— Record of periodical phenomena, arrival of birds, &c., at Palermo, New York, for nineteen years, from 1851 to 1869, inclusive.

Bath and North of England Agricultural Journal.—On the temperature of the sea and its influence on the climate and agriculture of the British Isles. By Nicholas Whitley, F. M. S. (Reprinted by permission.) 8°. 36 pp. London, 1869.

Boardman, G. A.—Thermometrical observations made on the St. John River, Florida, between Jacksonville and Enterprise, during the months of January, February, March, and April, 1869.

Bruhns, Dr. C.—Resultate aus den meteorologischen Beobachtungen angestellt an den fünfundzwanzig Königlichen Sächsischen Stationen im Jahre 1867. 4°. 71 pp. Leipzig, 1869.

C. K. Towarzystwa Nankow, Krakow.—Materyaly do klimatografii galicyi, zebrani przez sekcyi meteorologiczna komisyi przyograficznej C. K. Towarzystwa Nankow. Rok, 1867. 8°. 209 pp. Rok, 1868. 8°. 253 pp.

Campbell, Prof.—Barometrical reports for the months of March, April and May, 1869, at Washington College, Virginia.

Clingman, T. L.—Notes on the climate of Western North Carolina. (Printed slip.)

Coe, Charles C.—Meteorological register kept at Hood's River, Oregon, during the years 1865–'66–'67 and 1868.

Collins, Colonel.—Hourly observations of the thermometer from 4 p. m., January 4, 1864, to 4 p. m. January 7, 1864, at Fort Laramie, Dakota Territory.

Corbett, Hon. H. W.—Weather record for eleven years, at Portland, Oregon, from 1858 to 1868, inclusive; kept by Mr. Thomas Frazer. (Newspaper slip.)

Crosier, Dr. E. S.—Meteorological registers for November and December, 1865, at New Albany, Indiana.

Dall, W. H.—Translation of meteorological register kept at St. Michaels, Ikagmut, and Nulato, Russian America, during the years 1842 and 1843.

Daubrée, M. A.—Expériences synthétiques relatives aux météorites. Paris, 1868. 8°. 68 pp.

Davenport Female College.—Meteorological report from the Daven-

port Female College, Lenoir, North Carolina, for the months of May, June, July, August and September, 1869.

Dove, H. W.—Ueber den Sturm vom 17 November 1866, von H. W. Dove, aus dem Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin, 1867, (mit 2 Tafeln.) Berlin, 1868. 4°. 49 pp.

Eldridge, W. V.—Abstract of meteorological observations at Golconda, Pope County, Illinois, during the year 1869.

Ellis, Jacob M.—Review of the weather at Philadelphia for each month of the year 1869. (Newspaper slips.)

French, J. B., agent Winnipisseogee Cotton and Woolen Manufacturing Company.—Register of rainfall at Laconia and Lake Village, New Hampshire, during the year 1869.

Galle, Professor Dr. J. G.—Ueber die Bahn des am 30 January 1868, beobachteten und bei Pultulsk im Königreiche Polen als Steinregen niedergefallenen Meteors durch die Atmosphäre von Professor Dr. J. G. Galle, Director der Sternwarte zu Breslau, 8°. 43 pp.

Goldericke, O. J.—Pamphlets and newspaper slips relating to the climate, &c., of Colorado Territory.

Goulier, C. M.—Etudes géometriques sur les étoiles filantes. Metz, 1868. 8°. pp. 154. (Extrait des Mémoires de l'Académie Impériale de Metz, année 1866 et 1867.

Grayson, A. J.—Meteorological observations, and remarks upon the climate of Mazatlan, Mexico.

Haidinger, W. Ritter von.—Elektrische Meteore am 20ten October, 1868, in Wien beobachtet. Bericht von W. Ritter von Haidinger, wirklichem Mitgliede der Kaiserlichen Akademie der Wissenschaften. (Mit 1 Tafel.) 8°. 12 pp.

Der Meteorsteinfall am 22 Mai 1868, bei Sclavetic. Zweiter Bericht von W. Ritter von Haidinger, Mitgliede der K Akademie der Wissenschaften, (mit 1 Tafel und 5 Holzschnitten.) 8°. 12 pp.

Der Meteorsteinfall von Sclavetic in Croatien, am 22 Mai 1868. Vorläufiger Bericht von W. Ritter von Haidinger, wirklichem Mitgliede der K Akadmie der Wissenschaften. 8°. 7 pp.

Huntingdon, G. C.—Climatalogy of Kelly's Island, Ohio. (Newspaper slip.)

—— Report of proceedings of Lake Shore Grape Growers Association, containing address by George C. Huntingdon on "Grape rot and the weather." (Newspaper slip.)

Ingram, Dr. J.—Record of periodical phenomena at Vineland, New Jersey, during the year 1868.

James, J. W.—Summary of meteorological observations during the year 1869 at Riley, McHenry County, Illinois. Also summary from 1861 to 1868 inclusive, and for each month of 1869.

Jones, Benjamin W.—Synopsis of meteorological observations made during the winter of 1868 and 1869 at Cottage Home, Surry County, Virginia.

Kaiserliche Academie der Wissenchaften, Wien.—Die Temperatur-Verhältnisse der Jahre 1848–'63, an den Stationen des österreichischen Beobachtungsnetzes, durch fünftägige Mittel dargestellt, von Dr. C. Jelinek. 4°. 146 pp., 2 Tafeln. Wien, 1869.

— Erster Bericht der ständigen Commission für die Adria. 8°. 122 pp. Wien, 1869.

Kongliga Svenska Vetenskaps Academien, Stockholm.—Meteorologiska Iakttagelser i Sverige. 1864, Sjette Bandet. Obl. 4°. 192 pp. 1865, Sjunde Bandet. Obl. 4°. 186 pp. 1866, Attonde Bandet, Obl. 4to. 182 pp.

Kaiserlich-Königliche Central Anstalt für Meteorologie und Erdmagnetism.—Jahrbücher von Dr. C. Jelinek. Neue Folge, iv Band. Jahrgang, 1867. 4°. 227 pp. Wien, 1869.

Kaiserlich-Königliche Sternwarte, Vienna.—Anleitung zur Anstellung meteorologischer Beobachtungen und Sammlung von Hilfstafeln, mit besonderer Rücksicht auf die meteorologischen Stationen in Oesterreich und Ungarn. Von Dr. Carl Jelinek. 8°. 173 pp.

— Normale fünftägige Wärmemittel für 88 Stationen, bezogen auf den 20-jährigen Zeitraum 1848–'67. Von Dr. Carl Jelinek. 8°. 43 pp.

— Beobachtungen an der K. K. Centralanstalt für Meteorologie und Erdmagnetismus. 8°. 64 pp.

Lapham, Dr. I. A.—Atmospheric tide at Milwaukee, deduced from hourly observations at the time of new moon in October, November, and December 1868, and January and February 1869.

— Dates of opening and closing of the Milwaukee River from 1836 to 1869, inclusive.

Lull, James S.—Meteorological registers for 1860 to 1869, (portion of previous record interrupted by the war;) also, a table of rainfall from the 1st of May, 1853, until January 1, 1870.

Loehr, Charles H., United Statis consul, La Guayra, Ecuador.—Statistics from the United States consulate at La Guayra, South America, including particulars in reference to earthquakes, meteorology, &c.

Mapes, H. H.—Manuscript reports of the weather at various points in Kalamazoo and Allegan counties, Michigan, during each month of the year 1859.

McAulay, John P.—Thermometrical record kept at the Louisiana State Seminary, Alexandria, Louisiana, during the months of October, November, and December 1868, and January, February and March 1869.

McCall, C.—Monthly reports on the weather at Cathlamet, Waukiakum County, Washington Territory.

Merriam, C. C.—Manuscript meteorological report for January and February 1869, at Leyden, Lewis County, New York.

Merriam, C. L., Leyden, New York.—Newspaper slips containing remarks on the weather. Monthly.

Meteorological Observatory, Brisbane, Queensland, Australia.—Published meteorological report for April 1869.

Meteorological Office, London.—Charts of the surface temperature of the South Atlantic Ocean in each month of the year. Folio. 27 pp., 12 charts. London, 1869.

— Report on the meteorology of the North Atlantic, between the parallels of 40° and 50°, as illustrated by eight diagrams of observations taken on board of the mail steamers running to and from America, with remarks on the difference of the winds, &c. By Captain H. Toynbee, F. R. A. S. 8°. 8 charts. London, 1869.

— Report of the meteorological committee of the Royal Society for the year ending December 31, 1866. 8°. 72 pp. London, 1869.

Meteorological Society, London.—Proceedings issued monthly. 8vo.

— Meteorology of England for the quarter ending September 30, 1868. By James Glaisher, president Meteorological Society.

Montrose Natural History and Antiquarian Society, Montrose, Scotland.—Report of the directors for 1868, containing a meteorological register for the year.

Moss, G. B.—Summary of meteorological observations at Belvidere, Illinois, during the year 1869.

Mühry, Dr. Adolf.—Untersuchungen über die Theorie und das allgemeine geographische System der Winde. 8°. 254 pp. Göttingen, 1869.

Naturaliste Canadien.—Containing meteorological observations at Port Neuf and Montreal.

Naturforschende Gesellschaft, Basel.—Verhandlungen der Naturforschenden Gesellschaft in Basel, 1869. Containing: Bericht über einige Blitzschläge. Von Ed. Hagenbach.

Naturforscher Verein zu Riga.—Correspondenzblatt, 16ter Jahrgang, 1869. Containing meteorological observations at Riga, from September 1867 to July 1868, (new style,) inclusive.

Naturwissenschaftliche Gesellschaft, St. Gallen.—Bericht über die Thätigkeit der St. Galleschen Naturwissenschaftlichen Gesellschaft während des Vereinsjahres, 1867–'68. Containing: Einige Erfahrungen über klimatische Kuren und Kurorte. Von Dr. W. Steinlin.

Nelson, S. Augustus, Georgetown, Massachusetts.—Newspaper accounts of the great storms of September and October, in New England.

Observatoire Impérial de Paris.—Atlas des mouvements généraux de l'atmospèhre. Année 1865; Janvier, Février, Mars. Obl. folio. 90 charts. Atlas météorologique, 1867.

Observatoire Royal de Bruxelles.—Annales météorologiques. Bruxelles, 1868. 4°. 104 pp.

Osservatorio del Real Collegio Carlo Alberto in Moncalieri.—Bulletino meteorologico del Osservatorio del Real Colligea Carlo Alberto in Moncalieri, con corrispondenza del Osservatorio del Seminario di Alesssandria. Vols. i, ii, iii, (1865–'66–'67–'68,) 4°. Vol. i, 120 pp.; Vol. ii, 112 pp.; Vol. iii, 104 pp.

Paine, R. T.—Meteorological report for October, at Boston, Massachusetts, Newark, New Jersey, and St. Paul, Minnesota. (Newspaper slip.)

Parker, J. D., Steuben, Maine.—Newspaper accounts of the great storms of September and October, 1869, in Maine.

Printed abstract of meteorological register for 1860, at Portland, Maine, by Henry Willis. Also newspaper slips for several months of 1859 and 1861.

Pearce, T.—Weather record for September, 1869, at Ela, Polk County, Georgia.

Petterson, F., hospital steward, United States Army.—Table of mean temperature, humidity, and rainfall, at San Antonio, Texas, during the years 1868 and 1869.

Plantamour, E.—Résumé météorologique de l'année 1866, pour Genève et le Grand St. Bernard; par E Plantamour. Tiré des Archives des Sciences de la Biblitiothèque Universelle, Genève, September 1869, 8°. 232 pp.

— Résumé météorologique de l'année 1867, pour Genève et le Grand St. Bernard. Octobre 1868. 8°. 132 pp.

Real Osservatorio di Modena.—Sui coefficienti ozonometrici, dell' umidita e della temperatura, nota del Prof. D. Ragona. 8°. 10 pp.

— Sulle oscillazioni regolari ed irregolari della temperatura, dal Prof. D. Ragona. 8°. 12 pp.

— Riduzione della pressione atmosferica al medio-livello del mare, per gli stazioni meteorologiche italiane, del Prof. D. Ragona. 8°. 8 pp.

— Sulle variazioni diurne della temperatura e sul coefficiente di Kaemtz in Palermo. Lettera al chiar. Signor A. Quetelet, direttore del Real Osservatorio di Brussselles, del Prof. D. Ragona, direttore del Real Osservatorio di Palermo. Palermo, 1859. 8°. 54 pp.

— Osservazioni su la evaporazione, del Prof. D. Ragona. 4°. 8 pp.

— Riassunta delle osservazioni meteorologiche, eseguite nel Real Osservatorio di Modena nell anno 1866, dal Prof. D. Ragona, direttore dell osservatorio. Stessa. 4°. 7 pp.

— Sul calcolo dei valori medii in meteorologia, nota del Prof. D. Ragona, direttore dell Real Osservatorio di Modena. 4°. 2 pp.

— Descrizione del barometro registratore del Real Osservatorio di Modena, del Prof. D. Ragona. 4°. 8 pp.

— Sulle variazione periodicie del barometro nel clima di Milano, memoria di G. V. Schiaparelli e G. Celoria. 4°. 31 pp. Tav. iii.

Real Osservatorio di Palermo.—Giornale Astronomico e Meteorologico, pubbl. dal Prof. D. Ragona. Vol. i, Palermo, 1855. 4°. 375 pp., Vol. ii, Palermo, 1857. 4°. 391 pp., (three volumes in one.) Vol. iii, Palermo, 1859. 4°. 375 pp.

Regio Osservatorio dell Universita di Torino.—Bolletino meteorologico ed astronomico. Anno ii, 1868. Oblong 4°. 76 pp.

Roche, Edouard.—Recherches sur les affuscations du soliel et les méteioroscos miques. Paris, 1868. 4°. 80 pp.

Royal Observatory, Greenwich.—Results of magnetical and meteorological observations, 1866. 4°. 303 pp.

Sanford, Professor S. P.—Meterological registers for 1866–'67–'68, at Penfield, Georgia.

Sartorius, Dr. C.—Survey of meteorological observations at Mirador, Mexico, during the year 1868.

Sawyer, H., United States consul.—Newspaper slips containing meteorological observations at Paramaribo, Dutch Guiana, for the first half of the year 1869, (January to June, inclusive.)

Schweizerische Naturforschende Gesellschaft, Bern.—Schweizerische meteorologische Beobachtungen. 5ter Jahrgang, 1868. 4°. 22 pp, pl. 2. (Also September, November, December, 1868. 4°. pp. 470–622.)

Scottish Meteorological Society.—Journal for the half year ending June 30, 1868. Large 8°. 47 pp. Journal for the half year ending January, 1869, with tables for the quarter ending September, 1868. 8°. pp. 31.

Shepherd, Smiley.—Monthly means, &c., of temperature at Hennepin, Illinois, for 1869.

Sisson, R.—Mean temperature of twenty months, commencing April, 1868, at Factoryville, Pennsylvania, with comparisons of the month of November with former years.

Smith, G., hospital steward, United States Army.—Meteorological registers for the months of July and August, 1869, at Camp Date Creek, Arizona Territory.

Snow, Edwin M., M. D.—Fifteenth registration report, State of Rhode Island, 1867, (containing meteorological tables, and remarks by E. T. Caswell.)

Société d'Agriculture, Sciences, Arts et Belles-Lettres du Département d'Indre-et-Loire.—Annales. Containing: Observations météorologiques faites à Tours, par M. de Tastes.

Société d'Agriculture, Sciences et Arts de la Sarthe.—Bulletin. 112me série, tome xi, 1867–'68. Containing: Observations météorologiques faites à Mans, par M. Bonhomet.

Société d'Horticulture de l'Allier, Moulins, France.—Annales. Containing meteorological observations by M. Doumet, at Baleine, Allier, for a series of years, (1855–'66.)

Société Météorologique de France.—Annuaire de la Société Météorologique de France. Tome 5me, 1869, tableaux météorologiques, feuilles 7–11, 8°. 39 pp. Tome 6me, 1863, feuilles 1–5. Bulletin des sceances. 8°. 40 pp. Tableaux météorologiques. 8°. 40 pp. Nouvelles météorologiques. Pamphlet. Large 8°. 30 pp.

Stanley, J. H. S.—Monthly reports of the weather (mss.) at Houston, Texas.

Stewart, W. M.—Diagram of the annual quantity of rain fallen at Glenwood, Tennessee, from observations made during the years from 1851 to 1868, inclusive. (The same that is referred to on page 523 of Professor Safford's report on the geology of Tennessee.)

Thomas, Rev. C.—Copy of monthly aggregates from the rain register kept at Fort Garland, Colorado Territory, from April 1853 to September, 1869, inclusive.

Tutwiler, H.—Account of a meteorite observed near Frankfort, Alabama. (Newspaper slip.)

United States consulate, Valencia, Spain.—Newspaper slips with meteorological records made at the Meteorological Observatory of the University of Valencia.

Vacher, Dr.—Carte représentant la mortalité et l'état météorologique de Paris en 1865.

Verein der Freunde der Naturgeschichte in Mecklenburg, Güstrow.—Archive, 22te Jahre, 1869. Containing Uebersecht der aus den meteorologischen Beobachtungen zu Hinrichhagen im Jahre 1867 gefundenen Mittel, (20 Jahre.)

Vinal, W. I.—Weather record at Vinal Haven, Maine, during a portion of October, 1869.

Warren, W. J.—Record of the weather at Chilukweyuk Depot, Northwest Boundary Commission, from December 29, 1858, to April 24, 1859.

Whitaker, B.—Newspaper slips containing accounts of the weather at Warsaw, Illinois.

White, Captain A. T., United States revenue marine.—Meteorological register kept on board of the United States revenue steamer Wayanda, cruising on the coast of Alaska from May 13 to October 14, 1868.

Williams, Rev. R. G.—Hourly thermometrical and barometrical observations at Waterbury, Connecticut, and Castleton, Vermont, (in addition to regular observations on Smithsonian blanks.)

Zeledon, José.—Observaciones meteorologicas hechas en la cindad de San José durante el primer semestre de 1868. Oficina Central de Estadistica, San José.

Observaciones meteorologicas hechas en la cindad de Heredia (Costa Rica, Señor Rohrmoser) durante el año de 1868.

REPORT OF THE EXECUTIVE COMMITTEE.

WASHINGTON, D. C., *February* 1, 1870.

The Executive Committee of the Smithsonian Institution respectfully submits the following statement of the financial condition of Smithson's trust fund, and the application of the income for the year ending 31st December, 1869, with estimates of receipts and proposed appropriations for 1870:

The bequest of Smithson in the United States treasury is..		$541, 379 63
The Regents have added to this investment from savings, &c		108, 620 37
Making the Smithson fund in the U. S. Treasury, as a perpetual loan, at 6 per cent., on the 1st January, 1870....		650, 000 00
And in Virginia State 6 per cent. registered stock.	$53, 500	
With unpaid interest to January, 1867..........	19, 260	
	$72, 760	
The value of which, at the present time, may be estimated at 58 per cent		42, 200 80
Total invested capital		692, 200 80
And a cash balance in bank of		20, 969 65
Thus making Smithson's Trust Fund, on the 1st January, 1870		713, 170 45

RECEIPTS IN 1869.

Interest from the Treasurer of the United States, on $650,000, at 6 per cent., for the year ending 31st December, 1869	$39, 000 00
Premium on sale of gold, at 34¾ and 19¾ per cent. premium.	10, 515 20
Sales of publications	235 58
Sales of old and useless material	232 07
Repayment of expenses of explorations and collections...	732 15
Repayment for freights on literary and scientific exchanges.	517 56
Total income for the year 1869	51, 232 56
Cash balance in bank, January, 1869	10, 352 74
Amount available in 1869	$61, 585 30

In addition to this sum, the Institution received from and accounted for to the Department of the Interior the sum of $4,000, appropriated by Congress for the preservation and care of the property in the museum, collected by Government exploring expeditions.

Statement in detail of expenditures during the year 1869.

BUILDING.

For reconstruction of parts of building destroyed by fire	$1,764 70	
For general repairs of the building	2,345 25	
For furniture and fixtures, cases, carpets, stoves, &c	2,520 95	
		$6,630 90

GENERAL EXPENSES.

For meetings of the Board of Regents	$122 00	
For lighting the building	239 13	
For warming the building	1,389 77	
For postage	289 50	
For stationery	437 18	
For printing blanks, circulars, receipts, &c	322 25	
For tools, materials for cleaning and incidentals	328 89	
For salaries of secretary, chief clerk, and assistants	7,814 92	
		10,943 64

PUBLICATIONS AND RESEARCHES.

For publishing Smithsonian contributions, 4to	$1,987 18	
For publishing miscellaneous collections, 8vo	3,037 50	
For publishing Smithsonian reports, 8vo	1,458 55	
For meteorology, salaries of clerks and computers, rain gauges, and thermometers	1,581 10	
For apparatus for researches	146 80	
For explorations, natural history, and archæology in Mexico, Florida, Alaska, New Mexico, Hudson's Bay, Alabama, and Nova Scotia	611 54	
		8,822 67

LIBRARY, MUSEUM, AND EXCHANGES.

For purchase of books, periodicals, and binding	$436 04	
For literary and scientific exchanges, agencies at Leipsic, London, Paris, and Amsterdam	4,860 94	
For assistants in museum, janitor, watchmen, laborers, &c	5,307 50	
For incidentals to museum, freight, alcohol, taxidermy, &c	3,513 96	
For gallery of art: Portrait in oil of the late Dr. Robert Hare, who gave his collection of chemical and philosophical apparatus to the Institution	100 00	
		14,218 44
Expenditures during the year 1869		40,615 65
Deducting this amount from the receipts of the year and cash in bank in January, 1869, viz: receipts	$61,585 30	
Leaves a balance in bank, January, 1870		$20,969 65

ESTIMATES AND APPROPRIATIONS FOR 1870.

Receipts.

Interest on the Smithson Fund in the treasury of the United States, $650,000, payable 1st July, 1870, and 1st January, 1871, at 6 per cent. gold	$39,000 00
Probable premium on sale of coin, at 18 per cent	7,020 00
Interest on Virginia 6 per cent. stock, 1869, 2 per cent	1,454 00
Interest on Virginia 6 per cent. stock, 1870, 2 per cent	1,454 00
Sales of useless property, &c	500 00
Income for the year 1870	49,428 00

APPROPRIATIONS FOR THE YEAR 1870.

For general expenses	$12,000 00	
For publications and researches	15,000 00	
For museum and collections, not including the apropriation by Congress for care and preservation of the Wilkes and other exploring expeditions	6,000 00	
For literary and scientific exchanges	5,000 00	
For building and contingencies	5,000 00	
		43,000 00

EXAMINATION OF ACCOUNTS.

The committee examined 497 receipted vouchers for payments made during the four quarters of the year 1869. In every case the approval of the secretary of the Institution is given on the face of each voucher, and the certificate of an authorized agent of the Institution is appended to each voucher, setting forth that the materials and property and services rendered were for the Institution and applied to the purposes stated in the account.

The quarterly accounts-current, bank book, check book, and ledger were also examined, and showed that the payments were made in conformity with the regulations prescribed by the Regents, and that the cash balance stated in the accounts current for each quarter was in deposit to the credit of the Institution in the authorized depository, after all the quarterly accounts charged in the abstracts were paid.

In conclusion, the committee finds that all the expenses of the Institution have been paid in full to the end of the year, leaving a cash balance in bank on the 1st January, 1870, of $20,969 65.

All of which is respectfully submitted, by—

RICHARD DELAFIELD,
PETER PARKER,
JOHN MACLEAN,
Executive Committee.

JOURNAL OF PROCEEDINGS

OF

THE BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION.

WASHINGTON, D. C., *February* 3, 1870.

A meeting of the Board of Regents of the Smithsonian Institution was held on Thursday, February 3, 1870, at 7 o'clock p. m., at the Institution.

Present: Chief Justice Chase, Chancellor of the Institution, Messrs. Hamlin, Trumbull, Poland, Cox, Maclean, Delafield, Parker, and the secretary.

The minutes of the last meeting were read and adopted.

Professor Henry, the secretary, announced that Hon. Hannibal Hamlin, of the Senate, had been appointed a Regent, *vice* Mr. Fessenden, deceased; that Hon. James A. Garfield and L. P. Poland had been reappointed from the House of Representatives; and that Hon. S. S. Cox had been appointed, *vice* Mr. Pruyn, whose term had expired.

The secretary announced the death of Charles Armistead Alexander, esq., a valued collaborator of the Institution, whose series of spirited translations of the eulogies of eminent men, delivered before foreign academies, have added much value to the annual reports of this establishment, and have been received in several cases with much commendation by the original authors.

On motion of Dr. Maclean, it was

Resolved, That the Regents of the Smithsonian Institution recognize, in the death of Charles A. Alexander, esq., the loss of a valued collaborator, and that they sympathize with his friends and relatives in the bereavement to which they are subjected.

The secretary presented a general statement of the financial condition of the Institution.

General Delafield presented the annual report of the Executive Committee relative to the receipts and expenditures during the year 1869, and the estimates for the year 1870, which was read and accepted.

On motion of Dr. Maclean the secretary was directed to have an insurance effected on the east wing and range of the Smithsonian building to such amount as he may think necessary.

The secretary presented the eulogy on the late Professor A. D. Bache, which was received and ordered to be printed in the annual report.

General Delafield, for the Executive Committee, reported that they were still collecting facts and statistics relative to the city canal, and would hereafter present a further report.

The secretary stated that it was his painful duty to announce that since the last meeting of the Board the death had occurred of one of its most distinguished members—the Hon. William Pitt Fessenden.

Appropriate remarks were then made relative to the services, character, and virtues of the deceased, by Messrs. Trumbull, Hamlin, Parker, and the Chancellor, Chief Justice Chase.

On motion of Mr. Trumbull the following resolutions were adopted:

Resolved, That the Board of Regents of the Smithsonian Institution deeply mourn the loss of their distinguished fellow-regent, William Pitt Fessenden.

Resolved, That in the death of Mr. Fessenden our country has lost a refined and influential citizen, the Senate of the United States an able, judicious, honest statesman, and this Institution an active, intelligent, and learned Regent.

Resolved, That we sincerely condole with the afflicted family of Mr. Fessenden, and offer to them our heartfelt sympathy in their great bereavement.

Resolved, That a copy of these resolutions be communicated by the Secretary of the Smithsonian Institution to the family of the deceased.

Resolved, That Chief Justice Chase be requested to prepare a eulogy on Mr. Fessenden, for insertion in the journal of the Board of Regents.

General Delafield in behalf of the Executive Committee, stated that they deemed it highly important for the interests of the Institution in the promotion of science, and due to the secretary for his long and devoted services, that he should visit Europe to consult with the savans and societies of Great Britain and the continent, and he therefore hoped that a leave of absence would be granted to Professor Henry for several months, and that an allowance be made for his expenses.

On motion of Dr. Maclean, it was unanimously—

Resolved, That Professor Henry, Secretary of the Institution, be authorized to visit Europe in behalf of the interests of the Smithsonian Institution, and that he be granted from three to six months leave of absence, and two thousand dollars for traveling expenses for this purpose.

Judge Poland moved, that in consideration of the extra services which had been rendered by Mr. Rhees, chief clerk, since the death of Mr. Randolph, bookkeeper of the Institution, in auditing and keeping the accounts for the last three years, he be allowed $350, in addition to $250 already received, or $200 per year.

This proposition was advocated by the secretary, who considered it just not only in regard to the particular services in question, but also for his efficiency in the conduct of the general business of the establishment.

The motion was agreed to.

Adjourned to meet on the 10th instant, at 7 o'clock.

WASHINGTON, D. C., *February* 10, 1870.

A meeting of the Board of Regents of the Smithsonian Institution was held on Thursday, February 10, 1870, at 7 o'clock p. m., at the Institution.

Present, Messrs. Chase, Trumbull, Hamlin, Davis, Garfield, Poland, Delafield, Parker, Bowen, and the Secretary.

The Chancellor took the chair.

The minutes were read and approved.

Professor Henry presented his annual report, which was accepted.

On motion of General Garfield, it was—

Resolved, That the Executive Committee and the secretary be directed

to prepare a detailed statement of all the money expended on the museum during the past year, distinguishing between the items directly and exclusively chargeable to the care of the collections of the Government, and those of a contingent or indirect character.

Mr. Hamlin presented the following, which were adopted:

Having learned that the chief clerk of this Institution, Mr. William J. Rhees, is about to resign the office he has filled for seventeen years, to engage in an active business enterprise—

Resolved, That the Board of Regents highly appreciate his worth as a man, and his services as an officer of this Institution.

Resolved, That while they regret his resignation of an office which he has filled with honor to himself and advantage to the Institution, they hope that he may be equally successful in the career on which he is about to enter, and that a copy of these resolutions be presented to him by the secretary.

The Board then adjourned to meet at the call of the secretary.

[NOTE.—After this meeting the annual report was submitted to Congress and ordered to be printed; therefore, the subsequent proceedings of the Board for the session of the beginning of 1870 will be found in the next annual report.—J. H.]

GENERAL APPENDIX

TO THE

REPORT FOR 1869.

The object of this appendix is to illustrate the operations of the Institution by reports of lectures and extracts from correspondence, as well as to furnish information of a character suited especially to the meteorological observers and other persons interested in the promotion of knowledge.

KEPLER: HIS LIFE AND WORKS.

By M. Bertrand, *Member of the French Academy of Sciences.**

[*Translated for the Smithsonian Institution by C. A. Alexander.*]

The highest laws of the physical world have been established by geometers; the hypotheses on which those laws rest acquire real importance only after having been submitted to their decision; and yet the progress of natural philosophy would have been impossible if the great men to whom they are due, imbued only with a geometrical spirit, had regarded only its inflexible rigor.

Let us imagine a geometer initiated in the most elevated theories of abstract science. I speak not merely of a disciple of Euclid and Archimedes, but an intelligent reader of Jacobi and of Abel; and let us suppose that, while a stranger to every idea of astronomy, he should undertake to penetrate by his own independent efforts the general structure of the universe and the arrangement of its parts. Let us place him, moreover, in the most favorable conditions; let us admit that, free in spirit as Copernicus, he reposes not in the deceptive representations of the senses which, veiling from us the movements of the earth, have caused its immobility to be so long regarded as an axiom: what impossibilities will present themselves to his imagination! Borne along by an unknown movement, perceiving no fixed direction, no stable basis on which to rely for the determination of distances, he finds himself without data for the solution of the problem. Our geometer will attain, perhaps, to a conception of our own incommensurable littleness; but, perceiving no certain route, he will stop short by asserting in the name of a science which he believes infallible, because it leaves nothing to hazard, that, whatever the genius of man and the resources with which art may endow his organs, our path through space is to him as undiscoverable as would be that of a grain of dust borne on the wind to the animalcules which inhabit it.

Happily Pascal has gone too far in asserting that what transcends geometry lies beyond our reach. This discouraging appreciation takes no account of a sentiment implanted in the depths of the human soul; a sentiment which sustained Copernicus after having inspired Pythagoras. Outside of all demonstration, in effect man believes in the harmony of the universe and the simplicity of its mechanism; and, although imagination stands in strong contrast to geometry, the history of astronomy presents them to us united in a strict alliance; the former sustained by well-regulated reason, in some sort outstripping truth in order to reveal, as if by intuition, the beauty and general order of the system of worlds; the latter exerting its powers to test the true and the false, and by separating one from the other, finally to arrive at certainty.

The situation of the astronomer who seeks to divine the symmetrical and regular order of the celestial bodies, presents a certain degree of analogy with that of the philologist who, with unknown characters before

* *Mémoires de l'Académie de Sciences de l'Institut Impérial de France*, t. xxxv, 1866.

him, strives to reconstruct the words and ideas which they express. For the philologist as for the astronomer the problem is indeterminate, and it might be assumed that its solution is arbitrary; what assurance is there in fact that those strange figures are not simply decorative designs, capriciously traced without order and without object? And if they have in reality a meaning, no train of rigorous deductions can reveal it by leading us from the known to the unknown through a logical and sure chain of reasoning. It is necessary in such an inquiry to proceed tentatively, to accept conjectures founded on fugitive and remote analogies, to establish systems which the further study of facts will often overthrow, to frame hypotheses which will presently be rejected, but which will be patiently replaced by others, and to do this without discouragement, because the true solution, we may be certain in advance, will, when once detected and in whatsoever manner obtained, offer such a character of certainty that no further place will be left for doubt. The same is the case with the true astronomical systems; it is impossible to establish it by a series of rigorous deductions, and successively to demonstrate its different parts according to the method of the geometers. But, when a man of genius shall have divined, in whatever way it may be, the principles which reconcile the uniform and simple reality with the complex and variable appearances, judicious minds will at once recognize the truth of the hypothesis, without scrutinizing the means which have led to it, and without waiting for the solid and luminous proofs which, accumulating from age to age, will at length convert the most refractory by enlightening even the blindest.

It is not my purpose to retrace, here, the history of the efforts successively made in this direction, which would be the history of astronomy. From among the great men who, withdrawing the veils which hide it, have by degrees revealed the universe in its "full and sublime majesty," I have simply selected, in order to sketch the part which he performed, the most intrepid, persevering, and inspired of them all; by these terms I designate Kepler.

John Kepler was born at Weil, in Würtemberg, 27th of December, 1571, twenty-eight years after the death of Copernicus. His father, Henry Kepler, who belonged to the noble family of Keppel, was not worthy of such a son; he several times abandoned his wife, who herself was of evil reputation, and scarcely gave any attention to his four children. The early education of John was, therefore, much neglected; his mother, who could not read, sent him, it is true, to school, but kept him at home whenever his services could be turned to account in the inn, which reverse of fortune had reduced her to the necessity of keeping. The boy's weak constitution, fortunately, rendered him but little fit for such employments, and it was decided that he should study theology. At the age of thirteen he was gratuitously admitted into the Protestant seminary of Maulbronn; a favor easily obtained, for instruction was at that time propagated throughout Protestant Germany with a zeal equally liberal and enlightened. "It is the head and not the arm which governs the world," said the rector of the University of Maulbronn, in 1578; "there is need, then, of educated men, and such fruit does not grow upon trees."

From Maulbronn, Kepler, who advanced rapidly in his studies, passed to the seminary of Tübingen, where he applied himself to theology, but without giving to it his whole attention. He here composed some Latin verses on the ubiquity of the body of Christ, the elegant precision of which attracted the admiration of the secretary of the national deputies. Yet, when he quitted, at the age of twenty-two, the school of Tü-

bingen, he was not thought qualified to labor for the advancement of the church, and, furnished only with a flattering attestation of eloquence and capacity, he was named professor of mathematics and morals in the college of Grätz, in Styria.

The Archduke Charles, of Austria, who then governed Styria, professed the Catholic religion; but, what was very rare and little to be expected at that epoch, he extended to heretics an absolute tolerance; so that the Protestants, who then constituted a majority of the rich and enlightened classes, enjoyed full liberty to call to their service for all offices such of their co-religionists as had been instructed elsewhere. Hence it was, that Kepler received an invitation to Grätz. Instruction in astronomy being one of his duties, he was charged with the compilation of an almanac, and it was but natural that in a Catholic country, he should adopt the Gregorian reform which the Protestants obstinately rejected; choosing much rather, as was said, to be at variance with the sun than in accordance with the Pope. Kepler, who never consented under the most difficult circumstances to compound for the free expression of his religious sentiments, separated, on this occasion, from his co-religionists; the question, as he justly urged, was a purely scientific one. More than once in his career did he encounter it, and his opinion never varied. Sixteen years later, in 1613, in order to induce Germany to accept the new calendar, he composed, at the instance of the Emperor Matthias, a dialogue between two Catholics, two Protestants, and a mathematician, the latter of whom enlightens, and finally convinces the others; but Kepler was not equally successful with the Diet, to which the question was submitted, and, in spite of his efforts, the Gregorian reform was postponed till a long time afterward.

To increase the sale of his almanacs, Kepler did not shrink from inserting astrological predictions of political and other events, and, as a few happened to be realized nearly at the time predicted, not a little credit accrued to him on that account. His biographers have affirmed, however, that, superior to the prejudices of his age, he had no faith in astrological divination, but his correspondence shows that at this epoch, and even many years afterward, he was persuaded of the influence of the stars on events of every nature. In one of his letters he makes an applicatio nof his principles to the newly-born son of his master, Mœstlin, and announces that he is threatened with a great danger. "I doubt," he says, "whether he can survive it;" and, in fact, the child died. Just at that time one of his own children was also taken away; and when, on occasion of this double bereavement, we find him, with expressions of affectionate interest for his master, again speaking of the fears which he had conceived, how is it possible to believe that he was not in earnest? But his predictions were not always so exactly fulfilled, and, after being often deceived, Kepler became less and less credulous. Thus it fared with astrology as with many other errors which entered his mind without taking root. He said, indeed, that, as the daughter of astronomy, astrology ought to nourish her mother; and he continued during life to make for those who asked it, and for a consideration, predictions and horoscopes conformable to the rules of the art. But, so far from abusing the credulity of his clients, he avowed to them that, in his opinion, his conclusions should be regarded as uncertain and suspicious; telling them, as Tiresias tells Ulysses, (in Horace:) *Quicquid dicam aut erit aut non*—(What I may say will or will not come to pass.)

The first scientific work of Kepler is entitled *Mysterium cosmographicum*, and was composed during the earlier part of his residence at Grätz. I undertake to prove," he says in his preface, "that God, in creating

the universe and regulating the order of the cosmos, had in view the five regular bodies of geometry as known since the days of Pythagoras and Plato, and that he has fixed, according to those dimensions, the number of heavens, their proportions, and the relations of their movements."

It is impossible not to be struck with the confident ardor of the young author and his enthusiastic admiration for the wisdom which governs the world and the majesty of the problems to which his life was to be consecrated. "Happy the man," says he, "who devotes himself to the study of the heavens; he learns to set less value on what the world admires the most; the works of God are for him above all else, and their study will furnish him with the purest of enjoyments. Father of the world," he adds, "the creature whom Thou hast deigned to raise to the intelligent contemplation of Thy glory is like the king of a vast empire; he is almost comparable to a god, since he has learned to comprehend Thy thoughts." The theory which inspired such transports is to-day disavowed by science. That brilliant edifice was destined to crumble away, little by little, for want of sure foundations, and Kepler, at that epoch, may be likened, according to Bacon's happy comparison, to the lark which soars to the skies, but brings back nothing from her excursions.

He always entertained, however, a great tenderness for this first labor, and, although he himself has, in a second edition, pointed out grave errors, he insists that no debut in science was ever more happy. Of this work little is recollected but some solid and convincing arguments in favor of the system of Copernicus. Kepler does not hesitate to censure emphatically, in a note, the tribunal which had dared to place in the Index of the Lateran the works of the illustrious Pole. "When we have used," he says, "the edge of an axe upon iron, it cannot serve afterward even to cut wood." The calculations which he executed on this occasion served, so to speak, to clear the field which was to yield him so ample a harvest; and the learned world, not less charmed by the agreeable and brilliant form of his exposition than surprised by the novelty of his ideas, became attentive to what the young astronomer might in future submit to it.

Having acquired a modest competence by his marriage with the young and fair Barbara Müller, already the widow of a first and separated from a second husband by divorce, Kepler seemed permanently fixed in Styria, and devoted himself, amid general applause, to the study of the science in which he delighted. His correspondence shows him to have been, at this epoch, fully satisfied with his labors and in the serene enjoyment of domestic happiness. This period of sweet tranquillity and studious leisure makes its appearance in his life as a peaceful oasis, where he was to repose but for a short time, and which he was destined never to find again. The Archduke Charles had as successor his son Ferdinand, who, a far better Catholic than he, chose as generalissimo of his troops the holy Virgin, and made a vow to extinguish heresy in his estates; the most simple means was to drive out the heretics, and it was that to which he resorted. Kepler, protected by learned Jesuits, who knew how to appreciate his merit, was treated with an exceptional indulgence. After having been forced to quit Grätz, he was permitted to return on condition of observing due prudence and reserve. This, we must conclude, he did not do to a satisfactory degree; for, shortly after, he was banished anew, forty-five days being allowed him to sell or rent the lands of his wife. It was of such acts, doubtless, that a celebrated historian was thinking when he wrote that, without disturbance and

without cruelty, Ferdinand succeeded in suppressing the Protestant worship in Styria.

However this may be, Kepler, thus deprived of the means of subsistence and banished from Styria, where numerous friends had surrounded him, remained unshaken in his faith. The Counsellor Herwart in vain proposed to him terms of accommodation; his integrity could not be made to bend. Kepler, so ingenious in his researches, was by no means so in paltering with his conscience. Unable to yield his reason to the Catholic creed, he obstinately refused it his homage. The reasons on which he based his resolution, equally remote from the weakness which bends to persecution and the arrogance which braves it, are impressed with a calm and gentle dignity: "I am a Christian," he writes to Herwart, "attached to the confession of Augsburg by a thorough examination of the doctrine, not less than by the instruction of my parents. That is my faith; I have already suffered for it, and I know not the art of dissembling. Religion is for me a serious affair, which I cannot treat with levity." And he continued, without losing heart, to find a refuge in science, devoting to it his hours of labor, his studious watchings, the ardent yearnings of his enthusiastic intellect. But this could not wholly preclude the bitter thoughts of exile and of poverty; if little concerned for himself, he could not help feeling how nearly those afflictions touched those who were dear to him. "I entreat you," he writes to Mœstlin, "if there is a place vacant at Tübingen, contrive to obtain it for me; let me know," he adds, "the price of bread, of wine, and the necessaries of life, for my wife has not been accustomed to a diet of beans." It was under these trying circumstances that he received from the celebrated Tycho-Brahé, who had become acquainted with his adversity, a proposition to unite with him in the astronomical labors with which he had been charged by the Emperor Rudolph. Kepler did not hesitate, and repaired with his family to Prague.

Nothing could have been more fortunate for astronomy than the union of Kepler with such a man, whose researches, less brilliant perhaps than his own, are distinguished by a laborious precision, which no previous astronomer had ever carried to the same degree of perfection. Kepler, himself, seems to have foreseen all its advantages when, speaking of the observations accumulated by Tycho, he wrote the year previous to Mœstlin: "Tycho is loaded with riches which, like most of the rich, he makes no use of." He had practiced observation, in effect, for thirty-five years, without any preconceived idea, while keeping an exact and minute register of the phenomena of the heavens. These accumulated results, without directly disclosing the truth, were admirably calculated to preserve Kepler from error by furnishing a solid point of support to the boldness of his inventive genius, and as a limit established in advance to prohibit its excesses. Having soon afterwards become, by the death of Tycho, possessor of the precious materials destined to fertilize his ideas, he was not slow in perceiving that under the confusion of those elements, which he might justly compare to the scattered leaves of the Sibyl, was concealed an eternal and immutable order, and he sought it during nine years with the unwearied devotion which triumphs over discouragement, and with the energy which assures success.

But with a view to proceeding in order, he first directed his attention to the elimination of a cause of error already indicated by Tycho, and one with which all the astronomical observations are infected: he studied the laws of refraction.

Hipparchus relates that twice in the same day he had observed the sun in the equator, and consequently two equinoxes. From this Ptolemy

simply concludes that one of these observations is erroneous; but the same singularity presented itself on different occasions to Tycho, who, certain of his own skill and of the precision of his instruments, could not admit such an explanation. He pointed out the true cause in the refraction of the luminous rays, which, null at the zenith, acquires at the horizon its greatest value; consequently, when the sun is, in the morning, a little below the equator, the refraction, by elevating its rays, may produce the impression of the observation of the equinox. Some hours later, when the sun is nearing the zenith, the refraction is less, and this cause of depression, compensating for the distance which the sun has traversed in its orbit, may cause it to be observed anew in the equator.

Pliny cites another contradiction not less palpable, which, while equally showing the importance of the phenomenon of refraction, should have led the ancient astronomers to make it the subject of their study. "An eclipse of the moon," he says, "has been observed at the moment when the sun was still visible above the horizon." The moon consequently disappeared although the right line which joins its center with that of the sun appeared not to encounter the earth. The fact is a constant one; it was observed particularly by Mœstlin and by Tycho; yet there is evidently a necessity that the earth, in order to eclipse the moon by its shadow, must be placed in a right line between the moon and sun. It is undeniable, therefore, that the three bodies are really in a right line at the moment of the eclipse, and the phenomenon must be explained by the refraction which brings the two luminaries into an apparently simultaneous opposition above the horizon. It will be seen from these instances how important it is that this cause of error should be taken into account in the discussion of observations. The Arabian astronomer Alhazen and the Polonese Vitellion were the first to call attention to this point, and Tycho, who thoroughly felt its importance, gave still later a table of refractions relative to different inclinations.

The difficulty of such an investigation is readily perceived, not to say that any direct determination is impossible. Refraction is the angle formed by the right line which really connects the luminous body with our eye, and the line resulting from the direction in which it is perceived. Now, of these two directions the second alone is open to actual observation; the angle which it forms with the other cannot be measured, and it is necessary to calculate it by an indirect process. The continuous observation of a star followed from the zenith to the horizon might give it; the diurnal movement, the laws of which are not contested, causes the star, in effect, to describe a perfect circle in the heavens, and knowing at every instant where it ought to be, we may place to the account of refraction the observed irregularities.

The process followed by Tycho is a little different, but he was far from attaining the object in view; according to him, the refraction of the light of the stars completely ceases at 20° from the horizon; that of the sun, being more considerable, becomes null only at 45°. This is altogether inexact, refraction follows the same laws for all these luminaries, and becomes null only at the zenith. Kepler, therefore, took up the question from the beginning, and composed, under the modest title of *Paralipomena ad Vitallionem*, a complete treatise of optics. This work, though containing serious errors, is truly remarkable for the time when it was composed. We find therein the correct theory of telescopes, exact rules for determining the focal distance of lenses and the augmentative power of an instrument. Here, for the first time, was given an exact description of the eye and the explanation of its mechanism; it is here, finally, that we find an explanation of the cinereous light of the moon, at-

tributed in a spirit of loyalty to his old master Mœstlin. Although entirely misled as to an elementary law of refraction, Kepler has here calculated a table of astronomical refractions, which from the zenith to 70° does not differ more than 9″ from that adopted at present, but in approaching the horizon the deviations become more considerable. We recognize in this book the hand of no ordinary artificer; its perusal is embarrassed by few difficulties, and although in its doctrines tares be mingled in abundance with the good grain, the student who wishes to prove all things for himself would still find much to repay his labor. Descartes, who cites it with honor in his *Dioptrics*, expressly acknowledged the obligations which he owed to it.

But, while striving to attain the objects which he had proposed to himself, Kepler, as astronomer to the emperor, could not properly remain inattentive to the events which were taking place in the skies. He wrote, in 1606, a long dissertation on a star which had appeared in the constellation of the Serpent, and which, after having shone with a brilliancy greater than that of Jupiter, disappeared as mysteriously as it had come. This phenomenon, strange but not unexampled, caused a great sensation. "If I should be asked," said Kepler, "what will come to pass; what it is that this apparition forebodes? I shall answer without hesitation: First of all a flood of writings, published by numerous authors, and much labor for the printers. If I should be accused of having in my dissertation passed too slightingly over the theological and political consequences, I shall reply that my charge imposes on me the obligation of promoting astronomy to the best of my ability, but not of fulfilling the office of public prophet. I am glad of it; if I had to speak freely of all that passes in Europe and in the church, I should be much in danger of giving offense to all the world, for as Horace says,

"*Iliacos intra muros peccatur et extra.*"*

One would scarcely suppose on reading these lines that they were written in 1606!

He proceeds to inquire whence this star could have sprung and of what matter it was formed; but he does not succeed in solving the question, and concludes only that the blind force of atoms has nothing to do with it. Of this opinion also was his wife Barbara; Kepler tells us so in one of those personal digressions in which he sometimes indulges, and which are so vivid and sprightly that in reading them we almost seem to hear and see him, and at the same time are so naturally introduced that we feel no surprise at finding them mixed up with the serious thoughts on which he is intent. "Yesterday," he says, "fatigued with writing and troubled in mind with meditations upon atoms, I was called to dinner, and my wife placed a salad on the table. Do you think, said I to her, that if tin-plates, lettuce leaves, grains of salt, drops of oil and vinegar, and fragments of hard-boiled eggs had been floating in space ever since the creation, in every direction and without order, chance could have brought them together to-day to form a salad?—Not so good a one, I am certain, replied my fair spouse, nor so well made as this one is."

The treatise on the new star, which contains thirty chapters, leaves the reader as ignorant as the author himself was and as we to-day are of the nature and causes of the catastrophe which, from the presumed

* Trojans and Greeks, seditions, base, unjust,
Offend alike in violence and lust.—FRANCIS'S *translation.*

distance of the stars, must have been accomplished in the heavens and have troubled the systems of the cosmos many ages before the observations of Kepler.

After nine years of efforts prosecuted with an intense application of mind which sometimes, as he tells us, had tormented him almost to madness, *diu nos torserat ad insaniam*, Kepler succeeded in exactly representing the movement of Mars by two of the laws which have since been recognized as applicable to the other planets, and which have immortalized his name. His work is entitled: *Astronomia nova, seu Physica cœlestis*, &c. (The new astronomy, or celestial physics, founded on the study of the movement of Mars, deduced from the observations of Tycho-Brahé.) The preface, addressed to the Emperor Rudolph, furnishes a curious example of the spirit of the epoch, even more than of the genius of Kepler:

"I bring to your Majesty," he says, "a noble prisoner, a trophy of an arduous and long doubtful war, prosecuted under your auspices. Nor do I fear that he will refuse or scorn the name of captive, since it is not the first time that he has borne it; long ago, as we are informed, the terrible god of war fell ingloriously into the toils spread for him by Vulcan. Yet, until now, none had more completely triumphed over all human stratagems; it was in vain that the astronomers prepared every thing for the struggle; in vain that they brought all their resources into action and marshalled all their forces. Mars, mocking at their attempts, disconcerted their plans and baffled their hopes. Withdrawn in an impenetrable secrecy, he succeeded in veiling his skillful evolutions from hostile observation. The ancients complained of this deceptive strategy more than once, and that indefatigable explorer of the mysteries of nature, Pliny, pronounced Mars inscrutable to human eye.

"For myself, I ought first of all to extol the activity and pertinacity of the valiant chieftain Tycho-Brahé, who, under the auspices of the Danish sovereigns, Frederick and Christian, studied every night for twenty years the procedures of the enemy, in order to discover the plans of the campaign and the secret of his movements. The observations bequeathed to me by my predecessor have aided me in dispelling that vague and indefinite apprehension which is at first felt in the presence of a mysterious foe.

"During the uncertainties of the contest how many disasters have desolated our camp! The loss of an illustrious chieftain, sedition and desertion among the troops, contagious maladies, all contributed to augment our distress. Domestic solace and suffering alike interfered with business; a new enemy, as I have reported in my book on the late evanescent star, precipitated himself on the rear of our army; the veterans withdrew, the new recruits were untrained, and, worst of all, provisions were exhausted. Finally, however, the enemy became reconciled to peace, and by the mediation of his mother, Nature, sent me the avowal of his defeat. He surrendered on his parole, and Arithmetic and Geometry escorted him into our camp. From that time he has shown that he can be entirely trusted, and, content with his lot, asks but one favor of your majesty. All his family is in the sky; Jupiter is his father, Saturn his grandsire, Mercury his brother, and Venus his bosom friend and sister. Accustomed to their august society he is ardently desirous of recovering it, and would wish that like himself they were all received into your majesty's common hospitality. To that end it is important to profit by our success and to pursue the war with vigor; its hazards are at an end, since Mars is in our power. But I entreat your majesty to remember that money constitutes the nerves of war, and to be pleased to order

your treasurer to deliver to your general the sums necessary for the levy of new troops."

In commencing the study of the movements of Mars, it was incumbent on Kepler to ascertain with precision the time of its revolution, which was not unknown to Tycho, nor even to Ptolemy, who had calculated it with nearly equal exactness. It is a problem, in fact, which, notwithstanding its apparent difficulties, is of easy solution. The imaginary right line, called the radius vector, which connects the fixed center of the sun with the movable center of the planet, may be compared to the hand of a clock, and the time occupied in traversing its vast dial is the time of the revolution of Mars; the radius vector which unites the earth with the sun may be regarded as a shorter hand than the preceding and as turning in the same direction. The movement of the latter is well known; it makes its circuit in a year. Suppose, now, though it be not absolutely exact, that the planes of the two orbits coincide; in other terms that the two hands, of unequal length, move on the same dial-plate. Placed as we are at the extremity of the smaller, it is easy for us to note its coincidences with the greater, and the astronomers who attentively observe the sun and the planet Mars will be able to say at what moment we are on the line which unites them. It has been long known that these oppositions of Mars and the sun, or, what amounts to the same thing, the coincidences of the two hands of the dial, take place on a mean every 795 days. The longer hand, therefore, makes in 795 days one circuit less than the shorter; and as the movement of the latter is known to us, the tyro in astronomy can deduce therefrom the movement, assumed to be uniform; that is to say, the mean movement of the other. It is thus that the period of the revolution of Mars has been found equal to 687 days.

This result being well known to Kepler, he conceived the idea of collating, in the observations of Tycho, those which differed precisely by that number of days, and for which, consequently, Mars, after having accomplished a circuit, had returned to the same point of its course. He thus very ingeniously eluded the difficulty, apparently insurmountable, which results from its continual displacement in space. The two positions of the earth in its orbit being known through the previous study which had been made of its movement, the line which unites them becomes the base, at the two extremities of which the inquirer is considered as placed for the observation of a planet, which, having returned to the same position, may be regarded as motionless. One of the positions of Mars will thus be found with the date of two epochs, separated by an interval of 687 days, on which it has arrived at that place. By interposing other observations separated from the first by a period of two or three revolutions of the planet, the same result will be obtained, a result which furnishes a means of verifying the calculations, and at the same time, what is still more valuable, a confirmation of the hypothesis adopted for the law of the movement of the earth.

Encouraged by this first success, Kepler recommenced the operation a great number of times, following the planet step by step, in order, so to say, to stake out its course through space; but how many points are needed to determine the geometric nature of a curve? Rigorous geometry answers that, however great the number, it will not suffice, and that by any given points an infinite number of distinct curves of very different properties may always be made to pass; it is for this reason that so many tables admirably precise obtained by physicists have never been found susceptible, notwithstanding their efforts, of being converted into mathematical laws. The uncertainty and incompetence of science

in presence of such a problem require that patience should come to the aid of genius. Kepler attempted at first the verification of the hypotheses previously admitted, by seeking to place all his points on the same circle; but his efforts were futile; his calculations left errors of seven to eight minutes subsisting, and he proved that no better could be done. Eight minutes seem but a small matter; it is about a fourth of the apparent diameter of the sun; but it is in astronomy especially that it may be said with truth: *He who despises small things shall fall by little and little.* Kepler knew it, and this little error, which he was unwilling to accept, became considerable by its consequences. "The Divine Goodness," he says, "has given us in Tycho an observer so exact that an error of eight minutes is impossible." The hypothesis of a circular orbit was therefore inadmissible; but Kepler does not on that account despair of victory, nor is his confidence at all shaken. He fancies that, like the wanton Galatea (in Virgil,) Mars flies to covert, but in hiding wishes not to escape unseen:

Et fugit ad salices, et se cupit ante videri.

This is the first line of his fifty-eighth chapter.

After numerous attempts and laborious calculations, Kepler at last found that an elliptical orbit satisfies all the observations of Tycho; then it was that, as he expresses himself in his preface, he regarded Mars as a prisoner on parole. In a position thenceforth to interrogate the captive at leisure, he continued to press the inquiry more closely, by marking the places which the new theory indicated for the future, and he had the satisfaction of seeing the planet, punctual to the appointments which he had fixed, respond, so to say, to his summons, as the stars reply to their Creator in the book of Baruch, which La Fontaine so much admired: *You have called me; behold, I am here!*

This complete and persistent conformity furnished the irresistible evidence of the two celebrated laws which he could at length announce with certainty: Mars describes an ellipsis of which the sun occupies a focus. The areas described by the radius vector are proportional to the time.

But our statement of the great discovery of Kepler would be incomplete did we not particularize two remarkable circumstances which, coming fortuitously to the aid of his penetration, conducted him with more facility to the goal from which they might otherwise have turned him aside.

The movement of the earth, the presumed knowledge of which had served as a basis for all his calculations, was theoretically as imperfectly known as that of Mars. The circle in which he makes our planet move should be replaced by an ellipsis; but this ellipsis fortunately differs from a circle in a sufficiently small degree to render the substitution of one for the other a matter of indifference for the rate of approximation to be adopted. Had it been otherwise, the method would have become inexact, and the numbers, by contradicting one another, would have warned and discouraged the accurate and conscientious inquirer. The second circumstance, still more remarkable, perhaps, was the imperfection of the methods of observation and of the instruments of Tycho. Kepler might affirm, it is true, that an error of eight minutes was impossible, and this confidence saved everything; had he said as much of an error of eight seconds, all would have been lost. The internal organ of judgment, to use an expression of Gœthe, would have ceased to be in harmony with the external organ of sight, become too delicate and too precise.

Kepler had, in fact, deceived himself by regarding the important advantage obtained over the refractory and stubborn planet, as one of those decisive victories which forever terminate the contest; the great laws to which he had given expression, eternally true as they are within due limits, are not rigorous and mathematical. Numerous perturbations cause Mars incessantly to deviate from his path, and release him from time to time from the frail bonds in which the exulting calculator thought him entangled forever. For those, it is true, who are enabled to penetrate more deeply, the irregularities in question, once explained and foreseen, brilliantly confirm the theory of attraction which they both enlarge and elucidate; but the premature knowledge of those perturbations, a necessary consequence of more precise observations, would perhaps, by involving the truth in inextricable embarrassments, have retarded for a long time the progress of celestial mechanics. Kepler would then have been forced, since the elliptical orbit must have been rejected on the same grounds with the circular, to seek by direct means the laws of the disturbed movement, at the risk of exhausting, against insuperable obstacles, all the resources of his penetration and the obstinacy of his patience.

Kepler now conceived the idea of penetrating more deeply into the mysteries of nature and discovering the cause of the movements whose laws he had revealed. After having destroyed forever the old error of obligatory circular orbits, he announced the simple and true principle on which rests to-day all rational mechanics: the natural movement of a body is always rectilinear; but unfortunately he adds: "Provided there be not a soul which directs it," and this restriction mars everything. *Nego ullum motum perennam nòn rectum a Deo conditum esse, præsidio mentali destitutum.* There needs, according to this principle, an unceasing force to conduct the planet in its curved orbit, and this force resides in the sun. Kepler affirms this expressly: *Solis igitur corpus esse fontem virtutis quæ planetas omnes circumagit.* It is the doctrine of Newton, or to speak more generally, it is truth.

Admirers of Kepler have seen in the two phrases just quoted one of his highest titles to renown. On this point I cannot agree with them. Impatient of the mystery of the planetary movements, Kepler has here not been faithful to the inspirations of his genius; uncertain and irresolute, he has attempted on the contrary all kinds of explanations without adopting and vindicating any one of them, and when the true idea crossed his mind, he was not able to appreciate or employ it.

After having said that the cause of the movement is in the body of the sun, he supposes that the rotation of that orb is transmitted to the planets and impels them; he introduces, further, a magnetic force depending on the direction of the axis of the body thus impelled. Views of an extremely vague kind on the nature of attraction lead him moreover to believe that it is inversely proportional to the distance, and it has been remarked that with a very slight modification, his reasoning would have conducted him to the true law. That does not hinder him from believing that the planet, being sometimes nearer to the sun, sometimes more distant from it, must be alternately attracted and repelled. With a contradiction which shows beyond all else the uncertainty of his ideas, he asks whether the planet, comprising its force within itself, is not endowed with an active principle which guides as well as moves it, and without going so far as to accord to it the faculty of reasoning, he bestows upon it a *soul*, which, instructed as to the route it must follow for preserving the eternal order of the universe, directs and maintains it therein with unflagging power and exhaustless energy. But how,

upon this hypothesis, does the planet succeed in recognizing its path? The expression of its velocity necessarily includes sines, and admitting even that this soul has a perception of angles, by what mysterious operation, he asks, could it calculate the sines of those angles? Recurring, finally, to the idea of a magnetic attraction, he is apprehensive of a conflict between the magnetic power and the animal power. These confused reveries in which the genius of Kepler involves itself, make us involuntarily think of the words we have cited: "*Torquebar pæne ad insaniam;*" they add nothing to his glory; it imports little that interpolated among these opinions, which are so many errors, he has for once announced the truth without founding it upon solid reasons. When a traveler seeks his way in the darkness of a rayless night, and hesitating at every step, exclaims anxiously from time to time: Perhaps it is there! shall we praise his sagacity because he has happened for once to guess right and has then passed on?

It would be unjust, therefore, to claim for Kepler the discovery of universal attraction, but there is no room for surprise at this. Mechanics, scarcely in its infancy, did not enable him, however clear-sighted, to test his ideas on motive forces and to transform them into precise and calculated theories; the labors of Galileo and of Huyghens were necessary to prepare even Newton for this, his immortal achievement.

The studies and meditations of Kepler were often interrupted and constantly troubled by chagrins and embarrassments of every kind. The heirs of Tycho were entitled to a share in the property of the astronomic tables which Kepler had promised; they complained of his deferring their publication while he occupied his time with researches in physics and with empty speculations, while the celebrated astronomer Longomontanus constituted himself the organ of their reproaches and unjust suspicions. In a letter, at the outset of which he still treats Kepler as a learned man and a friend of long standing, he accuses him of indulging an *immoderate zeal in the refutation of the theories of Tycho*, of allowing himself to be diverted from the occupations of his office by the *passion for criticising everything*, and of *breaking*, by attacking the works of his friends, *the ties of affection which bound them to him.* "If my engagements had permitted," says Longomontanus, "I would have gone to Prague expressly to have an explanation with you; but," he adds with increasing acrimony, "of what, after all, my dear Kepler, do you so much vaunt yourself? All your researches rest on bases established by Tycho, in which you have changed nothing. You may persuade the ignorant, but cease to maintain absurdities before those who thoroughly understand the matter. You do not fear to compare the works of Tycho to the muck of the Augean stables, and, like another Hercules, announce yourself ready to cleanse them; but no one is deceived thereby or prefers you to our great astronomer. Your arrogance disgusts all sensible people."

Accusations so remote from truth could not wound Kepler. He despised all this empty objurgation which re-echoed around him. A few notes on the margin of the letter from Longomontanus show in what estimation our philosopher held it. "Pretty abuse," he writes; and again, "decent phrases, if you please, to disguise your spleen." His reply, in which he declines a useless discussion, displays unbounded kindliness; it enables us to discern the serenity of his mind and moderation of his character. "At the moment when I received your militant epistle, peace had long been made with the son-in-law of Tycho. You and I would resemble, in quarreling, Portuguese and English vessels which should fight in the Indies when peace was already ratified at

home. . . . . You blame my manner of accusing and refuting. I yield the point, though I do not think that I have deserved your reproaches. From you, my friend, there is no reproof which I do not accept. I regret that you did not come to Prague; I would have explained my theories, and you would have returned, I trust, fully satisfied. You jeer me. So be it; let us laugh together. But why accuse me of comparing the works of Tycho with the muck-heaps of Augeas? You had not my letters under your eye; you would have seen that they contained nothing of the kind. The name of Augeas has found a lodgment only in your own imagination. I do not dishonour my astronomical labors by scurrilities." And in concluding: "Adieu," he says; "write to me as soon as possible, to the end that I may know that my letter has changed your feelings in regard to me."

The peace with the heirs of Tycho was but a brief truce; they addressed themselves to the Emperor himself; but Rudolph, though incapable as Emperor and King, had an enlightened and sincere love for the sciences, and put aside all these importunate cavilings. Surrounded, however, with enemies and rebels, the Emperor of Germany could scarce pay his astronomer some light installments on the considerable amount which he had fixed as his salary, and Kepler, in order to support his family, was compelled to accept labor of every sort, to make almanacs, calculate horoscopes, and place his erudition at the service of every one who could pay for it.

After the death of Rudolph, his successor, Matthias, less favorable to science and not less embarrassed by the incurable divisions which distracted the empire, entirely abandoned the observatory of Prague, so that its labors were interrupted through the failure of the most indispensable supplies. Kepler was constrained to relinquish employments which no longer yielded him even bread, and to accept the functions of professor at the University of Linz. It was in this city that he lost his wife, Barbara. Not long afterward, in order, he said, to give a mother to his three children, but without affecting to have made by doing so any great sacrifice on their account, he married again. After having compared with much care and subtlety of discrimination, as we see in one of his letters, the merits and attractions of eleven young persons commended to him by his friends, he espoused Susannah Reutlinger, orphan daughter of a simple artisan, who had been carefully educated in one of the most distinguished boarding-schools of the country. "Her beauty, her habits, her form," he writes, "everything about her suits me. Patient and industrious, she will know how to conduct a modest household, and, though not in her first youth, she is of an age to learn all that may be wanting." This marriage was the occasion of an important work, in which Kepler shows by a new example that his genius, in its comprehensive survey, embraced all the departments of science. "As I was about to be married," he says in the preface, "and the vintage was abundant and wine cheap, it was incumbent on a good father of a family to make provision thereof and replenish his cellar. Having therefore bought several casks, the vintner, a few days after, made his appearance with a view to ascertain the price by measuring their capacity, and, without making any calculation, plunged an iron rod into each cask and at once pronounced its contents." Kepler then recalls that on the banks of the Rhine, doubtless because wine is there more costly, the trouble is taken of emptying the barrel in order to count exactly the number of quarts it contains. Is the much more expeditious method practiced in Austria sufficiently exact? "This is a question," says Kepler, "the study of which is not unworthy of a

geometer newly married;" and, to solve it, he proceeds to discuss problems of geometry which may be accounted among the most difficult which had been till then undertaken. A singular consequence deduced is the following:

"Under the influence of a good genius who was, no doubt, a geometer, the constructors of casks have given them precisely the form which, for a line of the same length as that measured by the gaugers, affords the greatest possible capacity; and, as in the neighborhood of the maximum the variations are insensible, small accidental deviations exert no appreciable influence on the capacity, the expeditious measurement of which is consequently sufficiently exact." This idea respecting maxima, thrown out in passing, but in such absolute terms, by Kepler, received its development twenty years later from Fermat, of whom it is one of the titles to honor.

Kepler adds: "Who will deny that nature alone, without any process of reasoning, can teach geometry, when our coopers, guided only by their eyes and an instinctive sense of the becoming, are thus seen to divine the form which best comports with an exact measurement?" In conformity, at the same time, with his habit of mingling reminiscences of the classic poets with his scientific labors, he terminates this treatise on the *Art of measuring casks* with two verses, imitated from Catullus, which, freely translated, signify that, when indulging in conviviality, we should not count the glasses:

Et quum pocula mille mensi erimus,
Conturbabimus illa, ne sciamus.

This very learned work could be of no assistance to Kepler in the support of his family, becoming every year more numerous; he was living, therefore, with great economy and amid continual anxieties for the future, when afflictions still more poignant came to embitter his latter years. A letter from his sister apprised him that their mother, at the advanced age of seventy, had just been cast into prison on an accusation of the crime of sorcery. Incensed at the impertinent absurdity of the questions addressed to her by the judge of instruction, Catharine Kepler had aggravated her position by becoming accuser in turn, and scornfully reproaching the magistrate with his abuse of office in the acquisition of sudden wealth. Unhappily, public opinion held her guilty, and without any precise allegation overwhelmed her with the odium of all the calamities of the vicinage; especially was general horror excited when the fact was established that she never looked any one in the face and had never been seen to shed a tear. These signs of malignity, it is true, were not conclusive, but as the judges, in impeachments of this kind, were absolved from the ordinary restraints and had no fear before their eyes but that of seeming too lenient, the usage was to extort by torture such confessions as would conduct the victim to the stake. Kepler hastened to the scene, and for five years of cruel apprehensions struggled unceasingly for the safety of his mother. Not all the prestige of his renown, however, nor his earnestness in demonstrating that "these tests of patience rather than of truth," as Montaigne expressed it, involve the judge in a deeper condemnation than that which he pronounces, could avail to hinder the instruments of torture from being exhibited to the aged Catharine, their uses explained to her, and their application threatened if her obstinate silence could not be otherwise overcome. But nothing could shake her constancy; she declared herself ready to suffer everything, and her lofty and resigned bearing saved her finally from the punishment, but not from the disgrace, which of course was reflected painfully on her son.

During these times of trouble and disorder all Germany, agitated, as it were, by a violent storm, seemed little else than a theater for the evolution of armies and the calamities which accompany them. One of the most terrible contests which history records, the war of thirty years, spread desolation and the contagion of deadly maladies through all the provinces. In this cruel extremity Kepler, who to assist his mother had renounced the functions of professor, was plunged in an ever-increasing destitution, against which his ardent spirit struggled without respite. But a last affliction was in reserve for him: he lost a daughter of the age of seventeen years. It was now that, bearing up against these distresses, he sought refuge in those serene regions into which the troubles of earth do not penetrate, and, casting aside the importunate burden of obligatory or lucrative labors, devoted all his thoughts to the composition of a work which, as he tells us, yielded him more pleasure than all its readers together could experience in its perusal. Those infinite spaces which surround us, whose eternal silence dismayed the sceptical reason of Pascal, possessed, in the harmonious diversity of movements which they accomplish, an inexhaustible attraction for the mystical imagination of Kepler; and as he thought that he had long heard in the depth of his soul the perpetual chorus of the mysterious voices of nature, he endeavored to give it utterance in the strange work entitled, "*Harmonices mundi, libri quinque*," Five books of the harmony of the world.

He first studies, geometrically, many regular figures, and the analytical views to which he is led would have sufficed, as one of our most distinguished colleagues has said, to preserve the work from oblivion. He reduces his problem to an equation, and interprets with exactness all its solutions. This, and nothing more, is regarded as within the scope of science at the present day; but such a result does not satisfy Kepler. "It is proved," he says, "that the sides of regular polygons must necessarily remain unknown, being, from their nature, undiscoverable. Nor is there anything surprising in the fact that *what occurs in the archetype of the world cannot be expressed in the conformation of its parts.*" Proceeding afterward to the consideration of human music, and recalling the idea of Pythagoras, who, we are told, compared the planets to the seven chords of the lyre, he aims to show how man, imitating the Creator, by a natural instinct is led, as regards the notes of his voice, to make the same choice and observe the same proportion which God has seen fit to introduce into the general harmony of the celestial movements; the same thought of the Creator being thus translated into all his designs, of which one may serve as the interpreter and figure for another.

Seeking harmonies wherever they are possible, Kepler devotes a chapter to politics: "Cyrus," he says, "having seen in childhood a man of tall stature clothed in short tunic, and near him a dwarf habited in a long and flowing robe, was of opinion that they should exchange garments in order that each might have what suited his size; but his master pronounced that each should be left in possession of what belonged to him. The two opinions might be reconciled by decreeing that the first should, after the exchange, give to the dwarf a certain sum of money. Every one," adds Kepler, "clearly sees by this example that a geometric proportion may be harmonic, such is 1, 2, 4, or the beneficial arrangement which gives to the tallest the longest robe. An arithmetical proportion may also be harmonic: such is 2, 3, 4, or the useful exchange which allows not the dwarf, possessing a long robe, to lose his property, but enables him to change it into money which he may apply to a better purpose."

This passage, which I translate as closely as possible, and I need not say without well comprehending its meaning, will suffice, I think, to give an idea of the chapter on politics. The last chapter of the work is occupied in determining precisely the nature of the planetary concords. Saturn and Jupiter constitute the bass, Mars the tenor, Venus the contralto, and Mercury the falsetto.

These obscure and chimerical ideas, in which the mind of Kepler wearies and loses itself, seem the profitless and vain amusement of an imagination released from the control of reason; we read on with sadness, without venturing to sound the mysterious depths of that great intellect led, by an inspiration without light, into the pure domain of phantasy. But in the last pages of the book the genius of the inspired dreamer awakens of a sudden to dictate to him those bold and august expressions which have become not less immortal than the discovery which they herald:

"Eight months since," he says, "I had a glimpse of the first ray of light; six months since I saw the dawn; a few days ago only did the sun arise in its transcendent glory. I give myself up to my enthusiasm, and venture to brave my fellow-mortals by the ingenuous avowal that I have stolen the golden vessels of the Egyptians in order to raise a tabernacle to my God far from the confines of Egypt. If I am pardoned I shall rejoice at it; if it is made a reproach to me I shall bear it; the die is cast. I write my book; whether it be read by the present age or by posterity imports little; it may well await a reader; has not God waited six thousand years for an observer of his works?"

Then, recurring to the precise language of science, he announces the celebrated law which, binding together all the elements of our system, connects the greater axes of the planetary orbits with the time of their revolutions. Nothing can be more unexpected than this vivid light, which seems to spring out of chaos; the astonished reader asks himself how it is that these precise rules and mathematical proportions appear all of a sudden in a world which Kepler seems to have been traversing as in a dream; how such abrupt clearness succeeds such profound obscurity, such pure melody the uncertain harmonies which precede it. There is nothing to-day to inform us. Kepler announces his law; verifies it, without communicating to us, as was his wont, the history of his ideas; and then, transported with the full and entire possession of one of the secrets longest and most ardently sought, he breaks forth into raptures of thanksgiving, and, not content with the common language of humanity, borrows the majestic symphonies of the Psalmist: "The wisdom of the Lord is infinite, so also are His glory and His power. Ye heavens, sing His praises! Sun, moon, and planets, glorify Him in your ineffable language! Celestial harmonies, and all ye who comprehend His marvelous works, praise Him! And thou, my soul, praise thy Creator! It is by Him and in Him that all exists. That which we know not is comprised in Him, as well as our vain science. To Him be praise, honor, and glory throughout eternity!"

And in a note not less animated, and more touching, perhaps, than the text, he adds: "Glory also to my old master, Mœstlin!"

The Emperor Matthias was dead. His successor was his nephew Ferdinand, of Austria, whose pious energy, intent on extirpating the Protestant worship in Styria, had, twenty years before, troubled the life of Kepler. His zeal had not relaxed, and the persecution was rekindled with increasing violence: "Whither shall I betake myself?" writes Kepler to a friend. "Should I seek a province already devastated, or one of those which will not fail soon to be so?" He had fortunately

preserved his friendly relations with the most distinguished of the Jesuits, and, as their influence over the mind of Ferdinand was unbounded, they managed, when Wallenstein was named duke of Friedland, to have an article introduced into the decree which might secure Kepler's safety by attaching him to the duke's service; it was also stipulated that the arrears of his salary as imperial astronomer should be paid out of the revenues of the duchy. But new difficulties soon arose: the gentle-spirited and affectionate Kepler, separated from his wife and children, could not become reconciled to the tumult and disorder of the camps. Little fitted for the calling of a courtier, he was deficient in the assiduity and pliancy necessary to win the favor of a haughty and imperious master, whose protection was but a disguised servitude. Wallenstein, seeing with extreme impatience the little faith reposed in the language of the stars by him whom he considered as his astrologer, did not long defer the dismissal of Kepler, replacing him by the Venetian, Seni, whose delusive and accommodating science flattered, to the last, the presumptuous ambition of a soldier who, as Schiller says, "could scarcely tolerate that his will was not authoritative even in the skies."

Kepler feared not, in his weakness, to dare the resentment of the all-powerful man who had imposed his laws on the Emperor himself; he demanded with pertinacity the payment of the sum stipulated in the imperial decree; but his strength was exhausted in vain in the numerous journeys rendered necessary by the prosecution of his claim, and he died at Ratisbon, in 1629, at the age of fifty-eight years.

By the union of the most opposite qualities, Kepler occupies in the history of science an altogether exceptional place. By evincing, from his first steps in the study of astronomy, the presumptuous hope of deciphering the enigma of nature, and of elevating himself by pure reasoning to a knowledge of the æsthetic views of the Creator, he seemed at first to wander with an insensate audacity, and without finding soundings or shore, over that vast and agitated ocean where Descartes, pursuing the same object, was destined soon to lose himself beyond retrieval; but, in the ardent and sincere aspirations of his soul toward truth, if the curiosity of Kepler disquiets and impels him, it never delivers him over to the blindness of self-conceit. Regarding as certain only what had been demonstrated, he was always ready to correct his determinations by the sacrifice of his most cherished discoveries as soon as a severe and laborious examination refused to confirm them; but what sublime emotions, what utterances of enthusiasm and exultation, when success has justified his temerity, and by persistent efforts he has attained his end! The noble pride which elevates and sometimes inflates his language has nothing in common with the vain-glorious satisfaction of a vulgar discoverer. Confident and daring when he is seeking, Kepler becomes modest and simple when what he seeks is found, and, in the transports of triumph, it is to God alone that he ascribes the praise. His soul, equally comprehensive and exalted, was without ambition as without vanity; he coveted neither the honors nor applause of men; affecting no superiority over the cultivators of science, obscure as they now are, to whom his correspondence is addressed, he never ceases to express the same respectful deference for the aged Mœstlin, whose sole glory in our eyes is that of having formed such a disciple. When, after having mastered his greatest discoveries, it became necessary for him to descend every day from the most exalted contemplations to struggle with the vulgar necessities of life, he never complained at seeing his merit overlooked or disputed, and always

accepted unaffectedly, without murmuring or repining, the labors and employments, whatever they might be, which would aid him in the sustenance of his family.

The laws of Kepler are the solid and impregnable foundation of modern astronomy, the immutable and eternal rule of the displacement of the heavenly bodies in space; no other discovery, perhaps, has better justified the words of the sage: *He who increases knowledge increases labor;* no other has given birth to more numerous researches and greater discoveries; but the long and laborious route which led to it is known but to the few. None of the numerous writings of Kepler are regarded as classical; his renown alone will be immortal; it is written in the heavens; the progress of science can neither diminish nor obscure it, and the planets, by the always constant succession of their regular movements, will proclaim it from age to age.

[NOTE.—Nothing is wanting to the completeness of the above memoir; but, having been addressed in the first instance to an assemblage of men of science, the learned author has probably thought it superfluous to give so distinct and formal a statement of the three laws, as they are called, of Kepler, (*Regulæ Kepleri,*) as it may be convenient for the general reader to have beneath his eye. For this reason, the following brief exposition of those celebrated astronomical axioms is here transcribed from the Encyclopedia Americana.—TR.

"The first of these laws is that the planets do not move, as Copernicus had imagined, in circles, but in ellipses, of which the sun is in one of the foci. For this, Kepler was indebted to the observations which Tycho had made on the planet Mars, whose eccentricity is considerable, and agrees particularly with the rule; in determining which Kepler went through an indescribably laborious analysis. The second law is, that an imaginary straight line from the sun to the planets, *radius vector*, always describes equal sectors in equal times. By this rule Kepler calculated his tables, imagining the whole plane of revolution divided into a number of such sectors, and, from this, he investigated their respective angles at the sun. This was called *Kepler's problem*. The third law teaches that, in the motion of the planets, the squares of the times of revolution are as the cubes of the mean distances from the sun; one instance of the application of which law, in the want of other means, is in the determination of the distance of the planet Herschel from the sun, it having been ascertained that its time of revolution amounts to a little more than eighty-two years."

EULOGY ON THOMAS YOUNG.

By M. Arago.

READ AT A PUBLIC SITTING OF THE ACADEMY OF SCIENCES, NOVEMBER 26, 1832.

[The previous eulogies which have been published in the appendix to the Smithsonian report, have been translated for the Institution from the original French. The following eulogy, however, is reprinted from a translation by the late Baden Powell, professor of natural philosophy in the university of Oxford.—J. H.]

Gentlemen: It seems as if death, who is incessantly thinning our ranks, directed his stroke with a fatal predilection against that class of our body, so limited in number, our foreign associates. In a short space of time the Academy has lost, from the lists of its members, Herschel, whose bold ideas on the structure of the universe have acquired every year more of probability; Piazzi, who, on the first day of the present century, presented our solar system with a new planet; Watt, who, if not the inventor of the steam-engine, the inventor having been a Frenchman,* was at least the creator of so many admirable contrivances by the aid of which the little instrument of Papin has become the most ingenious, the most useful, the most powerful means of applying industry; Volta, who has been immortalized by his electric pile; Davy, equally celebrated for the decomposition of the alkalies and for the invaluable safety-lamp of the miner; Wollaston, whom the English called the Pope, because he never proved fallible in any of his numerous experiments, or of his subtile theoretical speculations; Jenner, lastly, whose discovery I have no need to extol in the presence of fathers of families. To pay to such of its distinguished ornaments the legitimate tribute of the regret, of the admiration, and of the gratitude of all men devoted to study, is one of the principal duties which the Academy imposes on those whom it invests with the responsible honor of speaking in its name in these solemn meetings. To pay this grand debt, with the least possible delay, seems an obligation not less imperative. Gentlemen, the native Academician always leaves behind him, among the colleagues with whom he has been united by the election of the Academy, many confidants of his secret thoughts, of the origin and course of his researches, of the vicissitudes which he has gone through. The foreign associate, on the contrary, resides far away from us; he rarely joins in our meetings; we know nothing of his life, his habits, his character, unless from the reports of travelers. When several years have passed over such fugitive documents, if we still find any traces of them, we cannot reckon on their accuracy. Literary intelligence which has not found a record in print is a sort of coin the circulation of which alters

* This is not the place to enter on the controversy respecting the invention of the steam-engine. It may, however, be remarked that we may be well content to allow it to remain a question of *degree*. Every tea-kettle is a steam-engine. A very slight and obvious contrivance will enable steam to raise a piston. Let any one define what he means precisely by the term steam-engine, and the question of priority of invention will be easily settled.—Translator.

at the same time the impression, the weight, and the inscription. These reflections tend to show why the names of such men as Herschel, Davy, or Volta ought to be mentioned in our assemblies before those of many celebrated Academicians whom death has snatched from our more immediate circle. Moreover, I hope that after what I shall be able to adduce, even in a few minutes, no one will be able to deny that the man of universal science, whose life I am about to describe, and whose labors I shall analyze, has some real claims to preference.

BIRTH OF YOUNG—HIS CHILDHOOD—FIRST ENTRANCE ON HIS SCIENTIFIC CAREER.

Thomas Young was born at Milverton, in the county of Somerset, June 13, 1773, of parents who belonged to the Society of Friends. He passed his earliest years at the house of his maternal grandfather, Mr. Robert Davies, of Minehead, whom the active business of commerce had not been able to divert from the cultivation of classical literature. Young could read fluently at the age of two years. His memory was extraordinary. In the intervals of his attendance at the house of a village schoolmistress in the neighborhood of Minehead, at four years old, he had learned by heart a number of English authors, and even several Latin poems, which he could repeat from beginning to end, although he did not understand a word of the language. The example of Young, like many others of celebrity recorded by biographers, may, then, contribute to keep up the common prepossession of so many good fathers of families, who see in certain lessons, according as they may be recited without faults on the one hand, or are badly learned on the other, infallible indications of an eternal mediocrity in the one case, or the beginning of a glorious career in the other. It would, indeed, be far from our object if these historical notices should tend to strengthen such prejudices. Thus, without wishing to weaken the vivid and pure emotions which every year the distribution of prizes excites, we may remind some, in order that they may not abandon themselves to dreams which they will not realize, and others, in order to fortify them against discouragement, that Picus de Mirandola, the phenix of learners of all ages and countries, became in mature age an insignificant writer; that Newton, that powerful intellect of whom Voltaire in some well-known lines asks the angels whether they are not jealous—the great Newton, we observe, made but indifferent progress in the classes of his school; that study had for him no attractions; that the first time he felt the wish to labor, it was merely to take the place of a turbulent schoolfellow who, by reason of his rank in the school, was seated on a form above him and annoyed him by kicks; that at the age of twenty-two he was a candidate for a fellowship at Cambridge, and was beaten by one Robert Uvedale, whose name but for this circumstance would have remained to this day perfectly unknown; that Fontenelle, lastly, was more ingenious than exact when he applied to Newton the words of Lucan, "It is not given to men to see the Nile feeble and at its source."

At the age of six years Young entered under a teacher at Bristol,* whose mediocrity was a fortunate circumstance for him. This, gentlemen, is no paradox; the pupil, not being able to accommodate himself to the slow and limited steps which his master took, became his own instructor. It is thus that those brilliant qualities developed themselves which too much aid would certainly have enervated.

*The master, whose name was King, at first kept school at Stapleton, and thence removed to Towneud, both near Bristol. Young's acquaintance with the surveyor commenced after he quitted that school. (See Peacock's Life, p. 5.)—TRANSLATOR.

Young was only eight years of age when chance, whose influence in the events of man's life is more considerable than our vanity often allows us to admit, took him from studies exclusively literary and revealed his real vocation. A surveyor of much merit in the neighborhood took a great fancy for him; he took him out into the country sometimes on holidays, and permitted him to amuse himself with his instruments of surveying and natural philosophy. The operations by whose aid the young scholar saw the distances and elevations of inaccessible objects determined powerfully struck his imagination; but soon several chapters of a mathematical dictionary made all that seemed mysterious in the matter disappear. From this moment, in his Holyday excursions, the quadrant took the place of the kite. In the evening, by way of amusement, the engineering novice calculated the heights measured in the morning.

From the age of nine to fourteen Young went to a school at Compton, in Dorsetshire, kept by Mr. Thomson, whose memory he always cherished. During these five years all the pupils of the school were occupied exclusively, according to the practice of English schools, in a minute study of the principal writers of Greece and Rome.* Young continually maintained his place at the head of his class, and yet he learned at the same time French, Italian, Hebrew, Persian, and Arabic; French and Italian, from the chance object of satisfying the curiosity of a schoolfellow, who possessed some works printed at Paris, of which he was desirous to know the contents; Hebrew, in order to read the Old Testament in the original; Persian and Arabic, with the view of deciding a question started at table, whether there were as marked differences between the Oriental languages as between those of Europe.

I perceive the necessity of mentioning that I write from authentic documents before I add that, during what might appear so fabulous a progress in languages, Young, during his walks at Compton, was seized with a violent passion for botany; and that being destitute of the means of magnifying objects of which naturalists make use when they wish to examine the delicate parts of plants, he undertook to construct a microscope himself, without any other guide than a description of the instrument in a work by Benjamin Martin; that to arrive at this difficult result it was necessary to acquire some skill in the art of turning; that the algebraic formulas of the optician having presented to him symbols of which he had no idea, (those of *fluxions*,) he was for a moment in great perplexity; but not being willing at last to give up the enlargement of his pistils and stamens, he found it more simple to learn the differential calculus, in order to comprehend the unlucky formula, than to send to the neighboring town to buy a microscope. The ardent activity of the juvenile Young had led him to exertions beyond the strength of his constitution. At the age of fourteen his health was sadly altered. Various indications excited fears of a disease of the lungs; but these menacing symptoms at length yielded to the prescriptions of art, and the anxious cares of which this malady made him the object on the part of all his relations.

It is rare among our neighbors on the other side of the Channel† that

* It would appear from Young's own account that a far more liberal system was really pursued in this school. Also, the praises of the usher, Josiah Jeffery, should never be omitted, who initiated Young at leisure hours into a variety of experimental and practical subjects, which contributed materially to his future success. (See Peacock's Life, p. 6.)—TRANSLATOR.

† The reader will of course make due allowance in this and many other passages for the ideas of a foreigner as to English habits. The anecdote of Young's penmanship which follows is differently given by Dr. Peacock, p. 12.—TRANSLATOR.

a rich person, intrusting his son to the care of a private instructor, does not seek for him a fellow-pupil of the same age among those who have been remarkable for their success. It was in this capacity that Young became, in 1787, the fellow-pupil of the grandson of Mr. David Barclay, of Youngsbury, in Hertfordshire. On the day of his first appearance there Mr. Barclay, who doubtless felt the right of showing himself somewhat exacting with a scholar of fourteen years of age, gave him several phrases to copy, with the view of ascertaining his skill in penmanship. Young, perhaps somewhat humiliated by this kind of trial, demanded, in order to satisfy him, permission to retire to another room; this absence being prolonged beyond the time which the transcription would have required, Mr. Barclay began to joke on the want of dexterity he must evince, when at length he reëntered the room. The copy was remarkably beautiful; no writing-master could have executed it better. As to the delay, there was no longer any need to speak of it, for "the little Quaker,"* as Mr. Barclay called him, had not been content to transcribe the English phrases set him; he had also translated them into nine different languages.

The preceptor, or, as they call him on the other side of the Channel, the *tutor*, who had to direct the two scholars at Youngsbury, was a young man of much distinction, at that time entirely occupied in perfecting himself in the knowledge of the ancient languages. He was the future author† of *Calligraphia Græca*. He was not long, however, in perceiving the immense superiority of one of his pupils, and he recognized, with praiseworthy modesty, that in their common studies the true *tutor* was not always he who bore that title. At this period Young drew up, continually referring to the original sources, a detailed analysis of the numerous systems of philosophy which were professed in the different schools of Greece.‡ His friends spoke of this work with the most lively admiration. I know not whether the public is destined ever to see it. At all events, it was not without influence on the life of its author; for, in giving himself up to an attentive and minute examination of the singularities (to use a mild term) with which the conceptions of the Greek philosophers teemed, Young perceived that the attachment which he retained to the principles of the sect in which he was born became weakened. However, he did not separate entirely from it till some years afterward, during his sojourn in Edinburgh.

The little studious colony at Youngsbury quitted the country during some months in the winter, to reside in London. During one of these excursions Young met with a teacher worthy of him. He was initiated into chemistry by Dr. Higgins,§ whose name I can the less dispense with mentioning, since, in spite of his earnest and frequent remonstrances, there was an obstinate disinclination to acknowledge the share which legitimately belonged to him in the establishment of the theory of definite proportions, one of the most valuable discoveries of modern chemistry.

Dr. Brocklesby, the maternal uncle of Young, one of the most popular physicians in London at the time, justly confident of the distinguished success of the young scholar, communicated occasionally his productions to men of science and literature, and to men of the world, whose appro-

* This seems improbable, as Mr. Barclay's family were of the same sect.—TRANSLATOR.
† Mr. Hodgkin.
‡ This work is not mentioned by Dr. Peacock.—TRANSLATOR.
§ The share borne by Dr. Higgins in the suggestion or discovery of the atomic theory has been variously estimated. For an apparently perfectly fair view of the case, the reader is referred to Dr. Daubeny's Atomic Theory, p. 33.—TRANSLATOR.

bation might have greatly flattered his vanity. Young thus found himself at an early period in personal relation with those celebrated men, Burke and Wyndham of the House of Commons, and the Duke of Richmond. The last nobleman, then master of the ordnance, offered him the place of private secretary. The two other statesmen, although they wished him also to follow a career connected with the public administration, yet advised him first to go through a course of law at Cambridge.* With such powerful patrons, Young might reckon on one of those lucrative offices which persons in power are not slow to bestow on those who will spare them all study and application, and daily furnish them with the means of shining at the court, the council, the senate, without compromising their vanity by committing any indiscretion. Young, happily, had a consciousness of his powers; he perceived in himself the germ of those brilliant discoveries which have since adorned his name; he preferred the laborious but independent career of the man of letters to the golden chains which they exhibited so temptingly to his eyes. Honor be to him for such a determination! May his example serve as a lesson to so many young men whom political ambition diverts from a more noble vocation to transform themselves into mere officials, but who might learn, like Young, to turn their eyes to the future, and not sacrifice to the futile and transitory satisfaction of being surrounded by persons soliciting favors the solid testimonies of esteem and gratitude which the public rarely fails to offer to intellectual labors of a high order; and if it happen in the illusions of inexperience that they should think too heavy a sacrifice imposed on them, we would ask them to take a lesson of ambition from the mouth of a great captain, whose ambition knew no bounds; to meditate on the words which the First Consul, the victor of Marengo, addressed to one of our most honored colleagues (M. Lemercier) on the day when he, quite in accordance with his character, had just refused a place then of great importance, that of councilor of state:

"I understand, sir, you love literature, and you wish to belong altogether to it. I have nothing to oppose to this resolution. Yes; I, myself, if I had not become a general-in-chief and the instrument of the fate of a great nation, do you think I would have gone through the offices and the *salons* to put myself in dependence on whoever might happen to be in power in the position of minister or ambassador? No! no! I would have taken to the exact sciences. I would have made my way in the path of Galileo and Newton; and, since I have succeeded constantly in my great enterprises, truly I should have been equally distinguished by my scientific labors. I should have left behind me the remembrance of great discoveries. No other kind of glory would have tempted my ambition."

Young made choice of the profession of medicine, in which he hoped to find fortune and independence. His medical studies were commenced in London under Baillie and Cruikshank. He continued them at Edinburgh, where at that time Drs. Black, Munroe, and Gregory were in the height of their celebrity. It was only at Göttingen in the following year (1795) that he took the degree of doctor.† Before going

* "Mr. Wyndham advised him not to accept the appointment, and recommended him rather to proceed to Cambridge and study the law." (Peacock's Life, p. 45.)—TRANSLATOR.

† The author has omitted that, in 1797, Young entered as a fellow-commoner at Emanuel College, Cambridge, and in due time graduated there regularly in medicine, a step at that time necessary for his admission to the College of Physicians, in order to enable him to practice as a physician in London. (See Peacock's Life, p. 115.) In the university he was familiarly known by the name of "Phenomenon Young."—TRANSLATOR.

through this form, so empty, yet always so imperatively exacted, Young, hardly beyond the period of youth, had become known to the scientific world by a note relative to the gum ladanum; by the controversy which he sustained against Dr. Beddoes on the subject of Crawford's theory of heat; by a memoir on the habits of spiders, and the theory of Fabricius, the whole enriched with erudite researches; and, lastly, by an inquiry, on which I will enlarge on account of its great merit, the unusual favor with which it was received at its first production, and the neglect into which it has since fallen.

The Royal Society of London enjoys throughout the whole kingdom a vast and deserved consideration. The Philosophical Transactions which it publishes have been for more than a century and a half the glorious archives in which British genius holds it an honor to deposit its titles to the recognition of posterity. The wish to see his name inscribed in the list of fellow-laborers in this truly national collection beside the names of Newton, Bradley, Priestley, and Cavendish, has always been among the students of the celebrated universities of Cambridge, Oxford, Edinburgh, and Dublin* the most anxious as well as legitimate object of emulation. Here is always the highest point of ambition of the man of science; he does not aspire to it unless on occasion of some capital investigation; and the first attempts of his youth came before the public by a channel better suited to their importance, by the aid of one of those numerous periodicals which, among our neighbors, have contributed so much to the progress of human knowledge. Such is the ordinary course; such, consequently, ought not to have been the course followed by Young. At the age of twenty he addressed a paper to the Royal Society. The council, composed of the most eminent men of the society, honored this paper with their suffrage, and it soon after appeared in the Philosophical Transactions. The author treated in it of the subject of vision.

THEORY OF VISION.

The problem was anything but new. Plato and his disciples, four centuries before our era, were occupied with it; but at the present day their conceptions can hardly be cited but to justify the celebrated and little flattering sentence of Cicero: "There is nothing so absurd that it has not been said by some of the philosophers."

After passing over an interval of two thousand years, we must from Greece transport ourselves to Italy, if we should find any ideas on the wonderful subject of vision which merit the remembrance of the historian, where, without having ever, like the philosopher of Ægina, proudly closed their school against all who were not geometers, careful experimenters marked out the sole route by which it is permitted to man to arrive without false steps at the conquest of unknown regions of truth; there Maurolycus and Porta proclaimed to their contemporaries that the problem of discovering *what is* presents sufficient difficulties to render it at least somewhat presumptuous to cast ourselves upon the *world of intelligences* to search after *what ought to be;* there these two celebrated fellow-countrymen of Archimedes commenced the explanation of the functions of the different media of which the eye is composed, and showed themselves contented, as were at a later period Galileo and Newton, not to ascend above those kinds of knowledge which are capable of being elaborated or corrected by the aid of our

* And, it might be added, probably to a far more numerous class not of those bodies.—TRANSLATOR.

senses, and which have been stigmatized under the porticoes of the Academy by the contemptuous epithet of *simple opinion*. Such is always human weakness that, after having followed with a rare success the principal deviations which light undergoes in passing through the cornea and the crystalline, Maurolycus and Porta, when very near attaining their object, stopped short, as if before an insurmountable difficulty, when it was objected to their theory that objects ought to appear in an inverted position if the images formed in the eye are themselves inverted. The adventurous spirit of Kepler, on the contrary, did not remain embarrassed. It was from psychology that the attack originated; it was equally from psychology, clear, precise, and mathematical, that he overthrew the objection. Under the powerful hand of this great man the eye became, definitively, the simple optical apparatus known by the name of the *camera-obscura;* the retina is the ground of the picture, the crystalline replaces the glass lens.*

This assimilation, generally adopted since Kepler's time, remains open only to one difficulty; the *camera-obscura*, like an ordinary telescope, requires to be brought to *a proper focus*, according to the distance of objects. When objects are near, it is indispensable to increase the distance of the picture from the lens; a contrary movement becomes necessary as they become more distant. To preserve to the images all the distinctness which is desirable, without changing the position of the surface which receives them, is therefore impossible; at least, always supposing the curvature of the lens to remain invariable, that it cannot increase when we look at near objects, or diminish for distant objects.

Among the different modes of obtaining distinct images, nature has assuredly made a choice, since man *can* see with great distinctness at *very different* distances. The question thus put has afforded a wide subject of remark and discussion to physicists, and great names have figured in the debate. Kepler and Descartes held that the whole ball of the eye is susceptible of being elongated and flattened. Porterfield and Zinn contended that the crystalline lens was movable, and that it could place itself nearer to or further from the retina, as might be needed. Jurin and Musschenbrœck believed in a change in the curvature of the cornea. Sauvages and Bourdelot supposed also that a change in curvature took place, but only in the crystalline lens. Such is also the system of Young. Two memoirs, which our colleague successively submitted to the Royal Society of London, include the complete development of his views.

In the first of these the question is treated almost entirely in an anatomical point of view. Young there demonstrates, by the aid of direct observations of a very delicate kind, that the crystalline is endowed with a fibrous or muscular constitution, admirably adapted to all sorts of changes of form. This discovery overthrew the only solid objection which had, till then, opposed the hypothesis of Sauvages and Bourdelot. That hypothesis had no sooner been announced than it had been attacked by Hunter. Thus this celebrated anatomist aided the cause of the young experimenter by the attention drawn to the subject,

* The author seems to have left this illustration incomplete. Kepler's suggestion of the identity of the eye with the camera-obscura, after all, does not touch the difficulty of the *inversion* of the image. Nor has it been considered as completely cleared up even till much later times. The solution which, it is believed, is now most generally assented to is this: It is a law of our constitution, dependent on some physiological principle unknown, that we refer impressions on the retina to objects existing, or believed to exist, in the rectilinear direction *from which* the impression comes to the retina. Consequently, as rays cross at the pupil, falling on the *upper* part of the retina a ray suggests an object lying *below*, or an *inverted* image suggests an *erect* object.

while his labors were as yet unpublished, and not even communicated to any one. However, this point of the discussion soon lost its importance. The learned Leuwenhoek, armed with his powerful microscopes, traced out and gave figures of the muscular fibres in all their ramifications in the crystalline of a fish. To awaken the attention of the scientific world, tired with these long debates, nothing less was necessary than the high renown of the two new members of the Royal Society who entered the lists—one a celebrated anatomist; the other the most eminent instrument-maker of whom England could boast. These jointly presented to the Royal Society a memoir, the fruit of their combined labors, intended to establish the complete unalterability of the form of the crystalline. The scientific world was not prepared to admit that Sir Everard Home and Ramsden together could possibly make inaccurate experiments, or be deceived in micrometrical measurements. Young himself could not believe it, and in consequence he did not hesitate publicly to renounce his theory. This readiness to own himself vanquished, so rare in a young man of twenty-five, and especially on the occasion of a first publication, was, in this instance, an act of modesty without example. Young, however, had really nothing to retract. In 1800, after having withdrawn his former disavowal, our colleague developed anew the theory of the change of form of the crystalline in a memoir against which, from that time, no serious objection has been brought.

Nothing could be more simple than his line of argument; nothing more ingenious than his experiments. Young, in the first instance, got rid of the hypothesis of a change of curvature in the *cornea* by the aid of microscopic observations, which were of a kind to render the most minute variations appreciable. We can say more: he placed the eye in special conditions where changes of curvature in the cornea would have been without effect; he plunged the eye in water, and proved that there was still the same faculty of seeing at different distances preserved. The second of three possible suppositions, that of an alteration in the dimensions of the whole organ, was again overthrown by a multitude of objections and of experiments which it was difficult to resist.

The problem thus seemed finally settled. Who does not see, in fact, that if, of three only possible solutions, two are put out of the question the third is necessarily established; that if the radius of curvature of the cornea and the longitudinal *diameter of the whole eye* are invariable, it must follow that the form of the crystalline is invariable? Young, however, did not stop there; he proved directly, by the minute phenomena of the changes in the images, that the crystalline really changes its curvature; he invented, or at least gave perfection to, an instrument susceptible of being employed even by the least intelligent persons, and those least accustomed to delicate experiments, and armed with this new means of investigation, he assured himself that those individuals in whose eyes the crystalline has been removed in the operation for cataract did not enjoy the faculty of seeing equally distinctly at *all distances.**

* This instrument, called an "optometer," was originally proposed by Dr. Porterfield, and consists of a simple and ingenious contrivance for ascertaining the focal length of the eye, which varies so greatly in different individuals, and often in two eyes of the same person, and in the same eye under different conditions. Dr. Young greatly improved upon the original construction. It will be found described in the Lectures on Natural Philosophy, vol. ii, p. 576. The principle of it consists in measuring accurately the distance of an object from the eye at which perfectly distinct vision is obtained, and which is determined when the object seen through two small apertures close to the eye presents only a single image, while in other positions it shows two images.—TRANSLATOR.

We might fairly be astonished that this admirable theory of vision, this combination so well framed when the most ingenious reasonings and experiments lent each other mutual support, did not occupy that distinguished rank in the science of the country which it deserved. But to explain this anomaly, must we necessarily recur to a sort of fatality? Was Young then really, as he sometimes described himself with vexation, a new Cassandra, proclaiming incessantly important truths which his ungrateful contemporaries refused to receive? We should be less poetical but more true, it seems to me, if we remarked that the discoveries of Young were not known to the majority of those who would have been able to appreciate them. The physiologists did not read his able memoir, because in it he presumes upon more mathematical knowledge than is usually attained in that branch.

The physicists neglected it in their turn, because in oral lectures or printed works the public demands little more at the present day than superficial notions, which an ordinary mind can penetrate without difficulty. In, all this, whatever our distinguished colleague may have believed, we perceive nothing out of the ordinary course. Like all those who sound the greatest depths of science, he was misunderstood by the multitude; but the applauses of some of the select few ought to have recompensed him. In such a question we ought not to *count* the suffrages; it is more wise to *weigh* them.*

INTERFERENCES.

The most beautiful discovery of Young, that which will render his name imperishable, was suggested to him by an object in appearance very trivial—by those soap-bubbles so brilliantly colored, so light, which when just blown out of a pipe become the sport of every imper-

*Arago, in assigning the probable causes of the neglect of Young's speculations, seems to fall short of his usual point and perspicuity. It might be true that his memoir was neglected by physiologists because it was mathematical, and by parity of reason it might have been neglected by physicists and mathematicians as being physiological. But it is surely no reason to say that it was neglected by physicists *because* the public are superficial, &c. Young may have been in most of his speculations too profound for the many; but this particular instance of the structure of the eye and theory of vision is, perhaps, of all his researches, that which can be the least open to this charge. The subject is not itself abstruse; it is one easily understood by every educated person, without mathematical atttainments; and the point at issue was a simple question of fact, requiring no profound physiological knowledge to appreciate whether the crystalline has or has not a muscular structure capable of changing its convexity. The real state of the case seems to be very satisfactorily explained by Dean Peacock, (p. 36 *et seq.*,) from whose account, as well as from what has been since written, it appears, after all that has been done both by Dr. Young and others, that there is even at the present day considerable difference of opinion on the subject.

Perhaps the most comprehensive survey of the whole subject which recent investigation has produced will be found in the paper of Professor J. D. Forbes in the Edinburgh Transactions, vol. xvi, pt. i, 1845. After giving a summary view of preceding researches, and adverting to the prevalent opinion among men of science that the true explanation yet remains to be discovered, (most anatomists denying as a fact the existence of the *muscular* structure which Young conceived he had proved,) Professor Forbes proposes as his own view of the cause the consideration of the remarkable *variation in density* of the crystalline toward its central part; coats of different density, being disposed in different layers, may be acted on by the pressure of the humors of the eye when the external action of the muscle compresses them, and thus increase the curvature of the lens when the eye is directed to a near object, the whole consistence, especially in the outer parts, being of a gelatinous or compressible nature, and the central part more solid and more convex. Thus uniform pressure on the outer parts would tend to make the outer parts conform more nearly to the more convex interior nucleus.

It may be added that many physiologists are of opinion that, after all, there does not exist a sufficient compressive action on the ball of the eye to produce the effect supposed.—TRANSLATOR.

ceptible current of air. Before so enlightened an audience it would, without doubt, be superfluous to remark that the difficulty of producing a phenomenon, its variety, its utility to the arts, are not the necessary indications of its importance in a scientific point of view. I have, therefore, to connect with a child's sport the discovery which I proceed to analyze, with the certainty that its credit will not suffer from its origin. At any rate, I shall have no need to recall the apple, which, dropping from its stock and falling unexpectedly at the feet of Newton, developed the ideas of that great man respecting the simple and comprehensive laws which regulate the celestial motions; nor the frog and the touch of the bistoury, to which physical science has recently been indebted for the marvelous pile of Volta. Without referring in particular to soap-bubbles, I will suppose that a physicist has taken for the subject of experiment some distilled water, that is to say, a liquid which in its state of purity never shows any more than some very slight shade of color, blue or green, hardly sensible, and that only when the light traverses great thicknesses. I would next ask what we should think of his veracity if he were to announce to us, without further explanation, that to this water, so limpid, he could at pleasure communicate the most resplendent colors; that he knew how to make it violet, blue, green; then yellow like the peel of citron, or red of a scarlet tint, without affecting its purity, without mixing with it any foreign substance, without changing the proportions of its constituent gaseous elements. Would not the public regard our physicist as unworthy of all belief, especially when, after such strange assertions, he should add, that to produce color in water, it suffices to reduce it to the state of a thin film; that "thin" is, so to speak, the synonym of "colored;" that the passage of each tint into one the most different from it is the necessary consequence of a simple variation of the thickness of the liquid film; that this variation, for instance, in passing from red to green, is not the thousandth part of the thickness of a hair? Yet these incredible propositions are only the necessary consequences deduced from the accidental observation of the colors presented by soap-bubbles, and even by extremely thin films of all sorts of substances.

To comprehend how such phenomena have, during more than two thousand years, daily met the eyes of philosophers without exciting their attention, we have need to recollect to how few persons nature imparts the valuable faculty of being astonished to any purpose. Boyle was the first to penetrate into this rich mine. He confined himself, however, to the minute description of the varied circumstances which gave rise to these iridescent colors. Hooke, his fellow-laborer, went further. He believed that he had discovered the cause of this kind of colors in the coincidences of the rays, or, to speak in his own language, in the mutual action on each other of the *waves* reflected by the two surfaces of the thin film. This was, we may admit, a suggestion characteristic of genius; but it could not be made use of at an epoch when the compound nature of white light was not as yet understood.

Newton made the colors of thin films a favorite object of study. He devoted to them an entire book of his celebrated treatise, the "Optics." He established the laws of their formation by an admirably connected chain of experiments, which no one has since surpassed in excellence. In illuminating with homogeneous light the very regularly-formed series of bands of which Hooke had already made mention, and which originated round the point of contact of two lenses pressed closely together, he proved that for each species of simple color there exists, in thin films of every substance, a series of thicknesses gradually increasing,

at each of which no light is reflected from the film. This result was of capital importance; it included the key to all these phenomena.

Newton was less happy in the theoretical views which these remarkable observations suggested to him. To say, with him, that the luminous ray which is reflected is "in a fit of easy reflection;" to say that the ray which passes through the film entire is "in a fit of easy transmission"—what is it but to announce, in obscure terms, merely the same fact which the experiment with the two lenses has already taught us?*

The theory of Thomas Young is not amenable to this criticism. Here there is no longer admitted any peculiar kind of "fits" as primordial properties of the rays. The thin film is here assimilated in all respects to any thicker reflector of the same substance. If at certain points in its surface no light is visible, Young did not conclude that therefore its reflection had ceased; he supposed that, in the special directions of those points, the rays reflected by the second surface proceeded to meet with those reflected from the first surface, and completely destroyed them. This conflict of the rays is what the author designated by the term "*interference*," which has since become so famous.

Observe, then, here the most singular of hypotheses. We must certainly feel surprised at finding night in full sunshine at points where the rays of that luminary arrive freely; but who would have imagined that we should thence come to suppose that darkness could be engendered by adding light to light?

A physicist is truly eminent when he is able to announce any result which, to such an extent, clashes with all received ideas; but he ought, without delay, to support his views by demonstrative proofs, under the penalty of being assimilated to those Oriental writers whose fantastic reveries charmed the thousand and one nights of the Sultan Schahriar.

Young had not this degree of prudence. He showed at once that his theory would agree with the phenomena, but without going beyond mere possibility. When at a later period he arrived at real proofs of it, the public had other prepossessions, which he was not able to overcome. However, the experiment, whence our colleague deduced so memorable a discovery, could not excite the shadow of a doubt.†

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* In regard to the theory of the "fits," the author here seems to represent Newton's view as, in fact, mere tautology; while in other places he is supposed to have indulged in a visionary theory on the subject. Newton, however, expressly says: "What kind of action or disposition this is—whether it consists in a circulating or vibrating motion of the ray, or of the medium, or something else, I do not here inquire." (Optics, p. 255, ed. 1721.)

The fact is, Newton in his optical researches expressed the same avowed and systematic dislike in indulging in *any* gratuitous theories as in his other inquiries. "*Hypotheses non fingo*," was his motto in these as well as in other researches. In adopting the idea of "fits of easy reflection and transmission," we are of opinion that he did not violate that maxim, and that it was in fact the only legitimate first expression of the conclusion which the facts warranted. At certain points *no light appeared;* it was the legitimate inference, in the then state of knowledge, *that none was reflected.* But light was clearly under the same circumstances *transmitted;* at a distance a little greater along the ray, an opposite effect was witnessed; and so on. It was nothing more than the strict inference that at those points successively *something occurred* in the course of the ray which disposed it for, or induced, reflection in the one case, and non-reflection in the other; accompanied in the latter case by like tendency to transmission. These apparent "fits" must be still acknowledged as *phenomena;* the *mechanism* by which they are produced is, however, now known to be nothing inherent in the light, no essential property recurring, but the simple periodicity of conspiring or counteracting wave action.—TRANSLATOR.

† In the retrospective glance which the author thus gives over the progress of discovery previous to the period at which Dr. Young first entered on the field, what we have chiefly to observe is, that up to that date nothing like a connected view of the physical character of this wonderful agent had been attained; a few isolated specula-

Two rays proceeding from the same source by slightly unequal routes, crossed one another at a certain point in space. At this point was placed a sheet of white paper. Each ray, taken by itself, made the paper more bright at that point, but when the two rays united and arrived at that point together all brightness disappeared; complete night succeeded to day.

Two rays do not always annihilate each other completely at their point of intersection. Sometimes we observe only a partial weakening of intensity; sometimes, on the other hand, the rays conspire and increase the illumination. Everything depends on the difference in the length of route which they have gone through, and that according to

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tions had, indeed, been put forth respecting a theory of emitted molecules on the one hand, and of waves in an ethereal medium on the other, and a few experimental facts bearing on the choice between such hypotheses had been ascertained.

The several distinct phenomena of common reflection and refraction, of double refraction, of inflection or diffraction, and of the colored rings did not seem to be connected by any common principle, nor, even separately considered, could it be said that they were very satisfactorily explained. It was now the peculiar distinction of Young to perceive, and to establish in the most incontestable manner, a great principle of the simplest kind, which at once rendered the wave hypothesis applicable to the two last-named classes of facts, and thus directly connected them with the former. It is not always that we are enabled to trace the first rise and progress of the idea of a great discovery in the inventor's mind. We cannot forbear from here noticing that Dr. Young has left on record the progress of the first suggestions which occurred to him on the subject of interference. The first view which presented itself was that of the *analogies* furnished by *sound*, which, as is well known, is conveyed by means of waves propagated in air; and in the case of two sounds differing a very little from the same pitch, produced at the same time, we have not a continuous sound, but *beats*—that is, alternations of sound and silence; the waves in the one case conspiring with and reënforcing each other, in the other counteracting, neutralizing, and destroying each other. But in more special reference to light, Dr. Young's account of the origin of his ideas is so clear and striking that we must give it in his own words: "It was in May, 1801, that I discovered, by reflecting on the beautiful experiments of Newton, a law which appears to me to account for a greater variety of interesting phenomena than any other optical principle that has yet been made known. I shall endeavor to explain this law by a comparison: Suppose a number of equal waves of water to move upon the surface of a stagnant lake with a certain constant velocity, and to enter a narrow channel leading out of the lake. Suppose, then, another similar cause to have excited another equal series of waves, which arrive at the same channel with the same velocity, and at the same time with the first. Neither series of waves will destroy the other, but their effects will be combined; if they enter the channel in such a manner that the elevations of the one series coincide with those of the other, they must together produce a series of greater joint elevations; but if the elevations of one series are so situated as to correspond to the depressions of the other, they must exactly fill up those depressions, and the surface of the water must remain smooth; at least, I can discover no alternative, either from theory or from experiment. Now, I maintain that similar effects take place whenever two portions of light are thus mixed, and this I call the general law of the interference of light."—TRANSLATOR.

For the sake of many readers it may not be superfluous or useless here briefly to illustrate the application of these theoretical ideas. We have only to imagine in like manner, in the case of the rays of light, two sets of waves propagated through an ethereal medium and coinciding in direction, when it will be easily apparent that just as in the case of the supposed canal, they may have their waves either conspiring or counteracting, and consequently giving a point of brightness or darkness accordingly. Thus, a coincidence in the periods, or an interval of an integer number of entire wave-lengths would cause the two systems of waves to conspire and reënforce each other; a difference of periods of half a wave-length, or any odd number of half wave-lengths, would cause the two systems to counteract or neutralize each other. Thus, according to the thickness, there would be a point of darkness or of brightness for each primary ray, and the succession of tints would be perfectly explained.

This would directly apply to the *thin films*. A ray impinging would be partly reflected at the first surface of the thin film; partly entering, it would be reflected internally at its second surface, and emerge coinciding in *direction* with the first, but retarded behind it from the thickness traversed in its *undulations* either by a whole or half undulation, or some multiples of these, [illegible] either a point of brightness or one of dark[illegible] accordingly; or by some [illegible] fraction giving an intermediate shade. [illegible]

very simple laws, the discovery of which, in any age, would suffice to immortalize a physicist.

The differences of route which produce these conflicts between the rays, accompanied by their entire mutual destruction, have not the same numerical value for the differently colored primary rays. When two white rays cross, it is then possible that one of their chief constituent parts, the red for example, may alone be in a condition fit for mutual destruction. But white deprived of its red, becomes green. Thus, interference of light manifests itself in the phenomena of coloration. Thus, the different elementary colors are placed in evidence without any prism to separate them. We should, however, remark that there does

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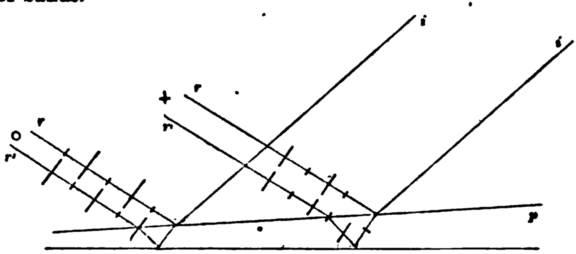
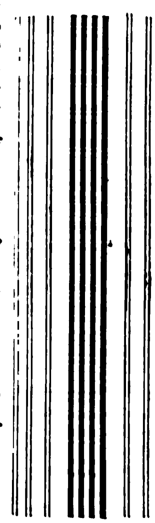
this would go on alternately at successively greater thicknesses of the film, giving a succession of such points or bands.

Thus, at two successive thicknesses of the plate p, the incident rays, falling on it in parallel directions i i, are reflected partially from the first surface r r, and partially from the second r' r'. According to the difference of thickness traversed, these may be in accordance giving a point of brightness as +, or in discordance giving a point of darkness as at o.



If two rays or sets of waves, instead of being exactly superimposed, be supposed to meet inclined at a very acute angle, in a somewhat similar way they would, at a series of points, alternately conspire or clash with each other, thus giving rise to a series of bright and dark points, the assemblage of which will produce bands or stripes on a screen intercepting the rays. Now, as to actual experimental cases, it was in the application of this latter theoretical idea that the invention of Dr. Young was peculiarly displayed. The former case was that alone which seems to have occurred to Hooke, in reference to the colors of thin plates, and even this was in his mind but a very indefinite conception; nor did it seem at first sight readily comparable with such cases as the diffraction fringes, or still less with the internal bands of a shadow observed by Grimaldi. If Hooke had imagined any theoretical views of this kind, it was probably confined to the one case of the thin films. Young's great merit was the comprehensiveness of his principle; and in following out the investigation he proceeded at once to such a generalization as evinced that comprehensiveness, and connected immediately those classes of phenomena apparently so different in character—the thin films, the internal bands, and the external fringes. When, as in Grimaldi's experiment, (since called the phenomena of diffraction,) a narrow slip of card was placed in a very narrow beam of solar light, dark and bright stripes parallel to the sides internally marked the whole shadow longitudinally, while the external fringes appeared on the outside at each edge. The general appearance of the shadow of a long narrow body with parallel sides in a beam of solar light issuing from a minute hole in a shutter, or, what is better, the focus of a small lens collecting the rays to a point, is that of a shadow marked with longitudinal stripes and externally bordered by parallel fringes or bands of light slightly colored, as seen in the annexed figure.



To *exhibit these* appearances ordinarily requires the sun's light. But the translator has found a very simple method of exhibiting these phenomena on a minute scale by candle light, by merely placing a fine wire across one surface of a lens of short focus, and looking through it at light admitted through a narrow slit parallel to the wire, or even the flame of a candle at a considerable distance.

Next, as to the theoretical explanation, an inspection of the accompanying diagram will perhaps help to convey an idea of the manner in which the several sets of waves are formed, and interfere in the case now supposed.

Young conceived the beam of light as a series of waves propagated onward till, on reaching the card, they were broken up into two new sets of waves, spreading in circles

not exist a single point in space where a thousand rays of the same origin do not proceed to cross one another after reflections more or less oblique, and we shall perceive at a glance the whole extent of the unexplored region which interferences open to the investigations of experimenters.

When Young published this theory, many phenomena of periodical colors had been already offered to the notice of observers, and, we should add, had resisted all attempts at explanation. Among the number we might instance the colored rings which are formed by reflection, not on thin films, but on mirrors of thick glass slightly concave; the iridescent bands of different breadths, with which the shadows of bodies are bordered on the outside, and in some instances covered within, which Grimaldi first noticed, and which afterward uselessly exercised the genius of Newton, and of which the completion of the theory was reserved for Fresnel; the bows, colored red and green, which are perceived in greater or less number immediately under the innermost of the prismatic bands of the rainbow,* and which seemed so completely inexplicable that the writers of elementary books on physics had given up making mention of them; and, lastly, the "coronas," or broad colored circles with varying diameters, which often appear surrounding the sun and moon.

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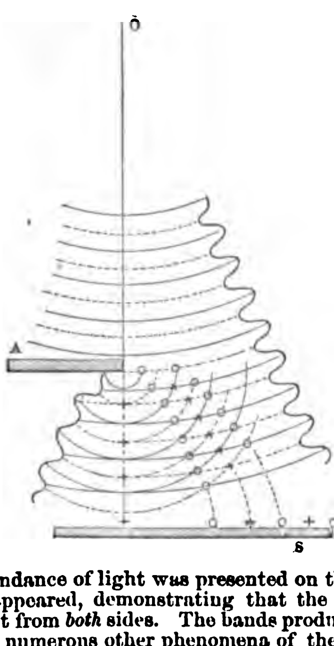
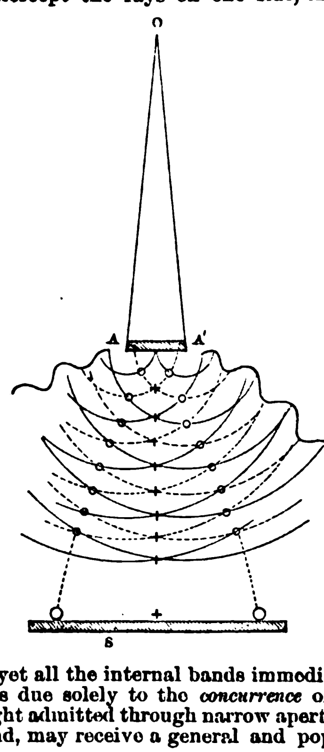
round each edge as a new center, while part of the original set continued to pass on at each side. On the principle just mentioned, these would *interfere* with the new portions on the outside; and the two new portions would *interfere* with each other in the inside of the shadow, in either case giving stripes or bands. To complete the proof, when an opaque screen was placed so as to intercept the rays on one side, though





abundance of light was presented on the other, yet all the internal bands immediately disappeared, demonstrating that the effect was due solely to the *concurrence* of the light from *both* sides. The bands produced by light admitted through narrow apertures, and numerous other phenomena of the same kind, may receive a general and popular explanation in the same way.—TRANSLATOR.

* This explanation has been recently controverted by Professor Potter.—Philosophical Magazine, May, 1855.

If I call to mind how many persons do not appreciate scientific theories except in proportion to the immediate applications which they may offer, I cannot terminate this enumeration of the phenomena which characterize the several series of more or less numerous periodical colors without mentioning the rings, so remarkable by their regularity of form and purity of tint, with which every brilliant light appears surrounded when we look at it through a mass of fine molecules or filaments of equal dimensions. These rings, in fact, suggested to Young the idea of an instrument, extremely simple, which he called an "eriometer," and with which we can measure, without difficulty, the dimensions of the most minute bodies. The eriometer, as yet so little known to observers, has an immense advantage over the microscope in giving at a single glance the *mean magnitude* of millions of particles which are contained in the field of view. It possesses, moreover, the singular property of remaining *silent* when the particles differ much in magnitude among themselves, or, in other words, when the question of determining their dimensions has no real meaning.

Young applied his eriometer to the measurement of the globules of blood in different classes of animals; to that of powders furnished by different species of vegetables; of the fineness of different kinds of fur used in the manufacture of different fabrics, from that of the beaver, the most valuable of all, down to that of the common sheep of the Sussex breed, which stands at the other extremity of the scale, and is composed of filaments four times and a half thicker than that of the beaver.

Before the researches of Young the numerous phenomena of colors* which I have just pointed out were not only inexplicable, but nothing had been found to connect them with each other. Newton, who was long engaged on the subject, had not perceived any connection between the rings in thin films and the bands of diffraction. Young reduced these two kinds of colored bands alike to the law of interference. At a later period, when the colored phenomena of polarization had been discovered, he observed in certain measures of the thickness at which they occurred some remarkable numerical analogies, which made it very reasonable to expect that sooner or later this singular kind of polarization would be found connected with his doctrine. He had in this instance, however, we must admit, a very wide hiatus to fill up. The knowledge of some important properties of light, then completely unknown, would have been necessary to permit him to conceive the whole singularity of the effects which, in certain crystals cut in certain directions, double refraction produces by the destruction of light resulting from the interference of rays; but it is to Young that the honor belongs of having opened the way; it was he who was the first to decipher these hieroglyphics of optics.†

*Every one may have remarked the threads of a spider's web occasionally exhibiting brilliant colors in the sunshine. The same thing is seen in fine scratches on the surface of polished metal, produced in a more regular way by the fine engraved parallel grooves in Barton's buttons. The colors of mother-of-pearl are of the same kind; all these colors Dr. Young showed were due to *interference* of the portions of light reflected from the sides of the narrow transparent thread or groove.—TRANSLATOR.

†It has been well observed that simplicity is not always a fruit of the first growth, and accordingly some of the earliest of Young's researches were complicated by unnecessary conditions. Thus, to exhibit the effect of two rays interfering, he at first not unnaturally transmitted the narrow beam of light through two small apertures near together. In point of fact, though the real effect is here seen, it is mixed up with others of a more complex kind. The narrow apertures each exhibited colored fringes in addition to the interference stripes seen between them. The colored fringes of *apertures*, unless very wide, are distinct from those formed by one external edge of an opaque body, the light from *each side* conspires to the effects in a somewhat complex

EGYPTIAN HIEROGLYPHICS—HISTORY OF THE FIRST EXACT INTERPRETATION GIVEN OF THEM.

The word hieroglyphic, regarded not metaphysically, but in its natural acceptation, carries us into a field which has been long the theater of numerous and animated debates. I have hesitated whether to risk

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manner. If the aperture be otherwise than long with parallel sides, the phenomenon becomes still more complex, and the calculation difficult; few such cases have ever yet been solved, and some such cases have been dwelt upon as formidable objections to the theory; they are simply cases to which the formula, from its mathematical difficulties, has not yet been extended.

In all these cases of diffraction an *opaque* body was used, and it might still be suspected that *some action of the edge* of that body might be concerned in the result. Numerous experiments of Maraldi, Dutour, Biot, and others were directed to the investigation of this point. Biot showed that an *opaque* body was not necessary, inasmuch as the edge of the plate *of glass*, or even the bounding line of two faces of a glass, cut at a slight inclination to each other, gave the same fringes; indeed, Newton also had noticed something of the kind. Haldat varied the conditions of the edge in every conceivable way, whether of form or nature, by the influence of magnetism, galvanism, electricity, or temperature from freezing to a red heat, without producing the slightest difference in the fringes—a result which it would be impossible to conceive compatible with any idea of an atmosphere of attraction or repulsion surrounding the edge.

Again: Though we have given the explanation of the *external* fringes in its simple and correct form, yet both Young and Fresnel failed in the first instance to see it in that light, both believing that the *reflection* of a portion of rays from the *edge* of the opaque body was *mainly* concerned in producing the interference. Subsequent experiments showed that even in cases where that edge reflects any sensible amount of light, its influence on the diffracted fringes is quite inappreciable. In fact, Young, in a letter to Fresnel, in returning thanks for a copy of a later memoir, in which he had shown this supposition to be unnecessary, also concurs in abandoning it. It did but complicate and injure the beauty of the result, (Young's Works, i, 393;) and every doubt must have disappeared in the minds of those who compared the minute arithmetical accuracy with which the places of the fringes, as computed from the simple theory in the investigations of Fresnel, agreed with those actually determined by the nicest micrometrical measurments.

In enumerating the discoveries of Young in the first establishment of the wave theory, it is somewhat singular that Arago, whether from accident or design, should have overlooked one investigation which must be regarded as among the most important. The great support which the emission theory received in recent times was that derived from Laplace's memoir on the law of double refraction, (1809,) in which, on the prinple of "least action," as maintained by Maupertius and applied to the idea of luminous molecules, he explained the observed laws of ordinary and extraordinary refraction in Iceland spar. This investigation exercised a powerful influence in favor of the molecular theory over the minds of the men of science in France, who bowed implicitly to the authority of Laplace. But the memoir of Laplace was the subject of a very powerful attack on the part of Dr. Young, carried on in an article in the Quarterly Review, November, 1809, in which he disputed the mechanical and mathematical grounds of Laplace's theory, and showed that the same laws of double refraction could be far more easily deduced from the undulatory hypothesis. Next to the discovery of interference, this refutation of the strongest point of the emission theory cannot but be regarded as one of the most material in the development and establishment of the undulatory view.

To the statement of these various cases of interference it should be added, that when the tints of polarized light were discovered, Young in 1814 applied to the phenomena the *general* consideration of *interference;* that is to say, he showed that, owing to the differing obliquities of the paths of the rays within the crystal, they would be unequally retarded in their passage, and would consequently emerge in conditions, with regard to length of route, respectively of accordance or discordance at corresponding distances round the central line or axis of the crystal, and thus might give rise to colored rings. Arago, however, soon noticed that the explanation was incomplete; the main point, in fact, remained to be accounted for, viz, why we see no colors till the *analyzer* is applied, and why even the previous polarization is necessary to the result. It was not until about two years afterward that Arago and Fresnel jointly succeeded in discovering a new law, which not only furnished the complete solution of the polarized rings, but at length cleared away all the difficulties which, from the first, had surrounde[illegible] polarization itself. For an account of this see memoir of Fresnel.—TR[illegible]

offending the feelings which this question has excited. The secretary of an academy occupied exclusively with the exact sciences might indeed, without impropriety, remit this philological subject to other more competent judges. I also feared, I will avow, to find myself in disagreement on several important points with the illustrious man of science whose labors it has been so delightful to me to analyze, without having to add a word of criticism from my pen. All these scruples, however, vanish when I reflect that the interpretation of hieroglyphics has been one of the most beautiful discoveries of our age; that Young himself has mixed up my name with discussions relating to it; that to examine whether France can pretend to this new title to glory, is to enhance the importance of the task confided to me at this moment, and to perform the duty of a good citizen. I am aware that some may find narrowness in these sentiments. I am not ignorant that the cosmopolitan spirit has its good side; but with what name shall I stigmatize it, if, when all neighboring nations enumerate with triumph the discoveries of their sons, it should hinder me from seeking, even in the present circle, among those colleagues whose modesty I would not hurt, the proof that France is not degenerate; that she also adds every year her glorious contingent to the vast deposit of human knowledge?*

I approach, then, the question of Egyptian writing, and I do so free from all prejudice, with the firm wish of being just; with the lively desire to conciliate the rival pretensions of two men of science, whose premature death has been to all Europe a legitimate subject of regret. Lastly, I shall not in this discussion on hieroglyphics transgress the bounds imposed on me; happy if those who listen to me, and whose indulgence I ask, may find that I have known how to escape the influence of a subject whose obscurity is proverbial.

Men have imagined two systems of writing entirely distinct. One is that employed by the Chinese, which is the system of hieroglyphics; the other, at present in use among all other nations, bears the name of the alphabetical or phonetic system.

The Chinese have no letters properly so called: the characters which they use in writing are strictly hieroglyphics; they do not represent *sounds* or articulations, but *ideas*. Thus a house is represented by a unique and special character, which does not change even when the Chinese have come to call a house, in their spoken language, by a name totally different from that which they formerly pronounced. Does this result appear surprising? Imagine the case of our ciphers, which are also hieroglyphics; the idea of one added to itself seven times is expressed everywhere in France, in England, in Spain, &c., by the aid of two circles placed vertically one over the other, and touching in one point; but in looking at this hieroglyphic sign (8) the Frenchman pronounces "huit," the Englishman "eight," the Spaniard "ocho." No one is ignorant that it is the same with compound numbers. Thus, to speak briefly, if the Chinese ideographic signs were generally adopted, as the Arabic numerals are, every one would read in his own language the works which they pre-

* In bringing out a part of this chapter on Egyptian hieroglyphics in the *Annuaire* for 1836, Arago has added: "The first exact interpretation which has been given of Egyptian hieroglyphics will certainly take its place among the most beautiful discoveries of the age. Besides, after the animated debates to which it has given birth, every one would desire to know whether France can *conscientiously* pretend to this new title to glory. Thus the importance of the question, and the national self-love properly understood, unite in encouraging me to publish the result of a minute examination to which I have devoted myself. Can I, then, be blind to the danger which there always is in attempting difficult subjects in matters which we have not made the special subject of our studies?"

sented to him, without the need of knowing a single word of the language spoken by the authors who have written them.

It is not so with alphabetical writing.

> "He who first taught us the ingenious art
> To paint our words, and speak them to our eyes,"

having made the capital remark that all words of a spoken language, even the most rich, are compounded of a very limited number of elementary articulate sounds, invented artificial *signs* or letters to the number of twenty-four or thirty to represent them. By the aid of these signs differently combined he could write every word which struck his ear, even without knowing the meaning of it.

The Chinese or hieroglyphic writing seems to be the infancy of the art. It is not always, as has been sometimes said, that to learn to read it, even in China, occupies the whole life of a studious Mandarin. Rémusat (whose name I cannot mention without recalling one of the most heavy losses which literature has lately sustained) has established, both by his own experience and by the fact of the excellent scholars he has formed every year by his lectures, that we may learn Chinese like any other language. It is not true, as was once imagined, that the characters are appropriated solely to the expression of common ideas; several pages of the romance of *Yu-kiao-li*, or The Two Cousins, will suffice to show that the most subtle abstractions, the quintessence of refinements, are not beyond the range of the Chinese writing. The chief fault of this mode of writing is, that it gives no means of expressing new names. A letter from Canton might have told at Pekin that on the 14th of June, 1800, a great and memorable battle saved France from great peril; but it would not have been able to express in these purely hieroglyphic characters that this glorious event took place near the village of Marengo, or that the victorious general was called Bonaparte. A people among whom the communication of proper names, from one place to another, could only take place by means of special messengers, would be, as we see, only in the first rudiments of civilization. These preliminary remarks are not useless. The question of priority, which the graphic methods of Egypt have called forth, thus comes to be easy to explain and to comprehend. As we proceed, in fact, we find in the hieroglyphics of the ancient people of the Pharoahs all the artifices of which the Chinese make use at the present day.

Many passages of Herodotus, of Diodorus Siculus, of Clement of Alexandria, have taught us that the Egyptians had two or three different sorts of writing, and that in one of these, at least, symbolic characters, or the representatives of ideas, played a principal part. Horapollon has even preserved to us the signification of a certain number of these characters. Thus we know that the *hawk* designated the *soul;* the *ibis*, the *heart;* the *dove*, (which might seem strange,) a *violent man;* the *flute*, an *alien;* the number *six*, *pleasure;* a *frog*, an *impudent man;* the *ant*, *wisdom;* a *running knot*, *love;* &c.

The signs thus preserved by Horapollon form only a very small part of the eight or nine hundred characters which have been found in the ancient inscriptions. The moderns, Kircher among others, have endeavored to enlarge the number. Their efforts have not given any useful result, unless it be so to show to what errors even the best-instructed men expose themselves when in the search after facts they abandon themselves without restraint to imagination. In the want of data, the interpretation of the Egyptian writings appeared for a long time, to all sound minds, a problem completely incapable of solution, when, in 1799, M. Boussard, an eng[illegible]r, discovered in the excavations which

he was making near Rosetta a large stone covered with inscriptions in three kinds of characters quite distinct.

One of the series of characters was Greek. This, in spite of some mutilations, made clearly known that the authors of the monument had ordained that the same inscription should be traced in three different sorts of characters, viz, in the sacred characters or Egyptian hieroglyphics, in the local or vulgar characters, and in Greek. Thus, by an unexpected good fortune, the philologists found themselves in possession of a Greek text, having also before them its translation into the Egyptian language, or at least a transcription in two sorts of characters anciently in use on the banks of the Nile.

This Rosetta stone, since so celebrated, and which M. Boussard presented to the Institute of Cairo, was taken from that body at the period when the French army evacuated Egypt. It was preserved, however, in the British Museum, where it figured, as Thomas Young said, as a monument of British valor. Putting valor out of the question, the celebrated philosopher might have added, without too much partiality, that this invaluable trilingual monument thus bears some witness to the advanced views which guided all the details of the memorable expedition into Egypt, as also to the indefatigable zeal of the distinguished savants whose labors, often carried on under the fire of the forts, have added so much to the glory of their country. The importance of the Rosetta stone struck them, in fact, so forcibly, that, in order not to abandon this precious treasure to the adventurous chances of a sea voyage, they earnestly applied themselves, from the first, to reproduce it by copies, by impressions taken in the way of printing from engravings, by molds in plaster or sulphur. We must add that antiquaries of all countries became first acquainted with the Rosetta stone from the designs given by the French savants.

One of the most illustrious members of the institute, M. Silvestre de Sacy, entered first in 1802 on the career which the trilingual inscription opened to the investigations of philologists. He only occupied himself on the Egyptian text in common characters. He there discovered the groups which represent the different proper names, and their phonetic nature. Thus, in one of two inscriptions, at least, the Egyptians had the signs of sounds, or true letters. This important result found no opponents after a Swedish man of science, M. Akerblad, in completing the labors of our fellow-countryman, had assigned, with a probability bordering on certainty, the phonetic value of each of the different characters employed in the transcription of the proper names which the Greek text disclosed. There remained all along the purely hieroglyphic part of the inscription, or what was supposed such; this remained untouched; no one had ventured to attempt to decipher it. It is here that we find Young declaring, as if by a species of inspiration, that in the multitude of sculptured signs on the stone representing either entire animals, or fantastic forms, or again instruments, products of art, or geometrical forms, those of these signs which were found inclosed in elliptic borders corresponded to the proper names in the Greek inscription, in particular to the name of Ptolemy, the only one which in the hieroglyphic inscription remains uninjured. Immediately afterward Young said that in the special case of the border or scroll, the signs included represented no longer ideas, but sounds. In a word, he sought by a minute and refined analysis to assign an individual hieroglyphic to each of the sounds which the ear receives in the name of Ptolemy in the Rosetta stone, and in that of Berenice in another monument. Thus we see, unless I mistake, in the researches of Young on the graphic sys-

tems of the Egyptians, the three culminating points. No one, it is said, had perceived them, or at least had pointed them out before the English philosopher. This opinion, although generally admitted, appears to me open to dispute. It is, in fact, certain that in 1766 M. de Guignes, in a printed memoir, had indicated that the *scrolls* in Egyptian inscriptions included all the proper names. Every one might also see in the same work the arguments on which the learned orientalist relied to establish the opinion which he had embraced on the constant phonetic character of the Egyptian hieroglyphics. Young, then, has the priority on this point alone. To him belongs the first attempt which had been made to decompose in letters the groups of the scrolls, to give a phonetic value to the hieroglyphics which composed in the stone of Rosetta the name of Ptolemy. In this research, as we might expect, Young furnished new proofs of his immense penetration; but, mislead by a false system, his efforts had not a full success. Thus sometimes he attributes to the hieroglyphic characters a value simply alphabetical. Further on he gives them a value which is syllabic or dissyllabic, without being struck by what must seem so strange in this mixture of different characters. The fragment of an alphabet published by Young includes, then, something both of truth and falsehood, but the false so much abounds that it would be impossible to apply the value of letters which compose it to any other reading than that of the two proper names from which it was derived. The word *impossible* is so rarely met with in the scientific career of Young, that I must hasten to justify it. I will say, then, that after the composition of his alphabet Young himself believed that he saw in the scroll of an Egyptian monument the name of "*Arsinoe*," where his celebrated competitor had since shown with irresistible evidence the word "*autocrator;*" that he believed he had found "*euergetes*" in a group where we ought to read "*Cæsar.*"

The labors of Champollion, as to the discovery of the phonetic value of hieroglyphics, are clear, distinct, and cannot involve any doubt. Each sign is equivalent to a single vowel or consonant. Its value is not arbitrary. Every phonetic hieroglyphic is the image of a physical object whose name in the Egyptian language commences with the vowel or the consonant which it is wished to represent.*

The alphabet of Champollion, once modeled from the stone of Rosetta and two or three other monuments, enables us to read inscriptions entirely different; for example, the name of Cleopatra on the obelisk of Philöë, long ago transported into England, and where Dr. Young, armed with his alphabet, could discover nothing. On the temple of Karnac, Champollion read twice the name of Alexander; on the Zodiac of Denderah, the title of a Roman emperor; on the grand edifice above which it is placed, the names and surnames of the emperors Augustus, Tiberius, Claudius, Nero, Domitian, &c. Thus, to speak briefly, we

* This will become clear to every one, if we seek, by following the Egyptian system, to compose hieroglyphics in the French language. A may be represented by (*agneau*) a lamb, (*aigle,*) an eagle, an ass, anemone, artichoke, &c.; B, by a balance, a whale, (*baleine,*) a boat, &c.; C, by *cabana,* (*badger,*) *cheval,* (horse,) cat, cedar, &c.; E, by *èpic,* (a sword,) elephant, *èpagneul,* (spaniel,) &c. *Abbé,* then, would be written in French hieroglyphics by putting any of the following figures in succession: A lamb, a balance, a whale, an elephant; or an eagle, a boat, a sword, &c. This kind of writing has some analogy, as we see, with the rebus in which confectioners wrap their *bonbons.* Thus we see at what stage these Egyptian priests were, of whom antiquity has so much boasted, but who, we must say, have taught us so little.

M. Champollion calls *homophones* all those signs which, representing the same sound or the same articulation, can be substituted indifferently for each other. In the actual state of the Egyptian alphabet I perceive six or seven homophone signs for A, and more than twelve for the Greek sigma.—ARAGO.

find on one hand the lively discussion to which the age of these monuments had given rise completely terminated; on the other, we observe it established beyond question that under the Roman dominion hieroglyphics were still in full use on the banks of the Nile.

The alphabet which had given such unhoped-for results, whether applied to the great obelisks at Karnac, or to other monuments which are also recognized as being of the age of the Pharaohs, presents to us the names of many other kings of this ancient race; the names of Egyptian deities; we can say more, substantives, adjectives, and verbs of the Coptic language. Young was then deceived when he regarded the phonetic hieroglyphics as a modern invention; when he advanced that they served solely for the transcription of proper names foreign to Egypt. M. de Guignes, and, above all, M. Étienne Quatremère established, on the contrary, a real fact, and one of great importance—that the reading of the inscriptions of the Pharaohs is corroborated by irresistible proofs, while they show that the existing Coptic language was that of the ancient subjects of Sesostris.

We now know the facts. I may, then, confine myself to confirm, by a few short observations, the consequences which appear to me to result from them.

Discussions of priority, even under the dominion of national prejudices, will have become embittered if they can be reduced to fixed rules; but in certain cases the first idea is everything; in others, the details offer the chief difficulties; sometimes the merit seems to consist less in the conception of a theory than in its demonstration. We then infer how much the choice of a particular point of view must depend on arbitrary conditions; and, lastly, how much influence it will have on the definite conclusion. To escape from these embarrassments, I have sought an example in which the parts respectively played by two rival claimants for an invention may be assimilated to those of Champollion and Young, and which has, on the other hand, united all opinions. This example, I believe, I have found in the *interferences*, even leaving out of the question, as regards the subject of the hieroglyphics, the quotations from the memoir of M. de Guignes. It is as follows: Hooke, in fact, had announced, before Dr. Young, that luminous rays interfered, just as the latter had asserted, before Champollion, that the Egyptian hieroglyphics are sometimes phonetic. Hooke did not prove directly his hypothesis; the proof of the phonetic values assigned by Young to different hieroglyphics could only rest on readings which had not, as yet, been made, and which could not then be made. From want of knowing the composition of white light, Hooke had not an exact idea of the nature of interferences, as Young on his part deceived himself by an imagined syllabic or dissyllabic value of hieroglyphics. Young, by unanimous consent, is regarded as the author of the theory of interferences. Thence, by a parity of reasoning which seems to me inevitable, Champollion ought to be regarded as the author of the discovery of hieroglyphics.

I regret not to have sooner thought of this comparison. If, in his lifetime, Young had been placed in the alternative of being the originator of the doctrine of interferences, leaving the hieroglyphics to Champollion, or to keep the hieroglyphics, giving up to Hooke the ingenious optical theory, I do not doubt he would have felt obliged to recognize the claims of our illustrious fellow-countryman. At all events, there would have remained with him what no one could have contested, the right to appear in the history of the memorable discovery of the interpretation of hieroglyphics in the same relative position as that in which

Kepler, Borelli, Hooke, and Wren appeared in the history of universal gravitation.

NOTE.—We have here put before our readers the literal version of Arago's statement respecting the claims of Young in regard to the discovery of the principle of interpreting the Egyptian hieroglyphics. Arago's representations have been, as is well known, greatly called in question. And though he throughout speaks in a tone of marked courtesy and candor toward Young, yet it is clear that he espouses the cause of Champollion with an ardor which many, in this country, believe has, in some degree, blinded him to the truth of the case. At any rate, in the vivid and highly-colored sketch here presented by M. Arago, the reader may need some caution in discriminating the fair share of merit which may be claimed by the respective parties engaged in the inquiry. The author's national partialities may very naturally have had some influence in biasing his judgment. It is impossible here to enter on details of controversy. But both as to the actual amount and accuracy of Dr. Young's investigations and the relative claims of M. Champollion, the reader may find it desirable to refer to the extended discussion of the subject given in Dr. Peacock's Life of Young. Without the pretension, or indeed the possibility, of adequately going into this question within the limits of such a commentary as can be here given, we shall content ourselves with pointing out to the notice of our readers a few of those passages in that work in which Dr. Young's claims are powerfully vindicated. The conclusions turn out such a variety of points of details that it would be wholly impracticable to attempt any analysis of them in this place. But the result tends to assign a considerably larger share of credit in the discovery to Dr. Young than Arago seems disposed to allow him. Dr. Peacock's able and elaborate work is doubtless in the hands of all those who take any interest in a question so important to the advance of philological and ethnological science as well as to general literature. Yet a slight sketch of the chief points referred to may not be useless.

We may first mention that Dr. Young's article "Egypt," in the Supplement to the Encyclopedia Britannica, published in 1819, contains the most comprehensive survey of his labors and conclusions on the subject of hieroglyphic literature up to that date. It does not profess to go into those minutiæ of critical detail, for which reference must be made to his numerous other writings on the subject; but as a general and popular view it will always be consulted with advantage. Nevertheless, the reader must always bear in mind that in the statements just given much had to be revised, or even reversed, from the improved disclosures of his later researches.

Dr. Peacock has alluded but briefly to the views of Arago, and toward the conclusion of the chapter sums up the representation of the case as given in the *éloge*, remarking only that the whole of his previous statements constitute the refutation of it.

The following extract will show the main claims of Young, insisted on by his biographer:

"It was Dr. Young who first determined, and by no easy process, that the rings* on the Rosetta stone contained the name of Ptolemy. It was Dr. Young who determined that the semicircle and oval, found at the end of the second ring, in connection with the former, was expressive of the feminine gender; and it was Dr. Young who had not only first

* Certain portions of the hieroglyphical characters are found surrounded by a ring or inclosure called by the French *cartouches*.

suggested that the characters in the ring of Ptolemy were phonetic, but had determined, with one very unimportant inaccuracy, the values of four of those which were common to the name of Cleopatra, which were required to be analyzed. All the principles involved in the discovery of an alphabet of phonetic hieroglyphics were not only distinctly laid down but fully exemplified by him; and it only required the further identification of one or two royal names with the rings, which expressed them in hieroglyphics, to extend the alphabet already known sufficiently to bring even names which were not already identified under its operation."

Dr. Peacock states that Champollion and Young, while engaged simultaneously in the prosecution of the researches connected with these points, in some instances had opportunities of personal communication with each other. But Champollion enjoyed especial advantages from circumstances which placed some of the papyri in his possession, and thus enabled him to take precedence in the publication of results; while his competitor, if he had enjoyed the same facilities, would, no doubt, have been equally competent to perceive the force of the new evidence thus adduced, and equally ready to make use of it, even if setting aside some of his earlier inferences and conjectures.

Dr. Peacock, after reflecting with much severity on Champollion, expresses his regret to find so eminent a writer as Chevalier Bunsen, whose remarks are quoted before, (p. 311,) "supporting, by the weight of his authority, some of the grossest of these misrepresentations," (p. 337.)

Dr. Young displayed singular modesty and forbearance in his controversy with Champollion, treating him throughout with all the respect due to his acknowledged eminence, and while mildly reproaching him with omitting to give him the due credit for his own share in the research, yet in no way insinuating that any discreditable motive led to the omission. Dr. Peacock, however, thinks a far more stringent tone of criticism might have fairly applied; he takes up the cause of Young with a less scrupulous zeal, and, though with perfect good temper, yet with deeply damaging force of argument and statement of facts, exposes the very unjustifiable nature of Champollion's assumptions, and vindicates the claims of Young to his fair and important share in these discoveries. He dwells on the tone of assumption in which Champollion presents himself to his readers as in exclusive possession of a province of which he had long since been the sole conqueror, and regards every question raised as to his exclusive rights as an unjustifiable attack to be resented and repelled, while he studiously suppresses the *dates* of the successive stages of the discovery, and thus attacks Young on the assertions made on imperfect knowledge in the earlier stages of his investigations with the aid of all his own accumulated information acquired subsequently, a proceeding the iniquity of which needs only stating to stand exposed. As instances of this, it is mentioned that Young, in 1816, on the strength of comparatively imperfect information then acquired, made some representations respecting the enchorial characters in the Rosetta inscription, and their relation to those employed in the funeral rolls. These Champollion criticises and exposes without reserve from the more full knowledge he had obtained in 1824, entirely passing over Young's own *later* statement on the same subject, correcting his former views, and from which even Dr. Peacock considers Champollion himself probably derived a large portion of his own knowledge of the subject. Dr. Peacock has collected in one point of view Champollion's main assertions as representing the state of the case. But he has

shown that some of the propositions dwelt upon were, in point of fact, *never maintained* by Dr. Young; and it was chiefly by his later researches that the erroneous impressions at first entertained, respecting the points to which they relate, had been corrected and their true nature established.

In 1821 Champollion denied altogether the existence of an alphabetic element among the hieroglyphics; but in the following year he adopted the whole of Young's principles, and applied them with one modification only. The analogy of certain marks in the Chinese hieroglyphics to signify proper names, the principle that the phonetic power of the symbol is derived from the initial letter or syllable of the name of the object which it represents in the Egyptian language, are among the chief of those which he borrows without acknowledgment, or claims without regard to their prior announcement by Young. "It would be difficult," says Dr. Peacock, "to point out in the history of literature a more flagrant example of disingenuous suppression of the real facts bearing on an important discovery."—TRANSLATOR.

MISCELLANEOUS WORKS OF DR. YOUNG.

The limits prescribed do not permit me even to quote the mere titles of all the numerous writings which Dr. Young published. Nevertheless the public reading of so rich a catalogue would certainly have sufficed to establish the celebrity of our colleague. Who would not imagine, in fact, that he had before him the register of the labors of several academies, and not those of a single individual, on hearing, for instance, the following list of titles:

Memoir on the Establishments where Iron is wrought.
Essays on Music and Painting.
Remarks on the Habits of Spiders and the Theory of Fabricius.
On the Stability of the Arches of Bridges.
On the Atmosphere of the Moon.
Description of a new Species of Opercularia.
Mathematical Theory of Epicycloidal Curves.
Restoration and Translation of different Greek Inscriptions.
On the Means of Strengthening the Construction of Ships of the Line.
On the Play of the Heart and of the Arteries in the Phenomena of Circulation.
Theory of Tides.
On the Diseases of the Chest.
On the Friction of the Axes of Machines.
On the Yellow Fever.
On the Calculation of Eclipses.
Essays on Grammar, &c.*

CHARACTER OF YOUNG—HIS POSITION AS A PHYSICIAN—HIS ENGAGEMENT ON THE NAUTICAL ALMANAC—HIS DEATH.

Labors so numerous and varied seem as if they must have required the laborious and retired life of that class of men of science, which, to say the truth, is beginning to disappear, who from their earliest youth separate themselves from their companions to shut themselves up completely in their studies. Thomas Young was, on the contrary, what is usually called a man of the world. He constantly frequented the best society in London. The graces of his wit, the elegance of his manners, were amply sufficient to make him remarkable. But when we figure to ourselves those numerous assemblies in which fifty different subjects in

* This list, it should be borne in mind, is intended by the author merely as a specimen of the vast catalog[illegible] might be made of Young's writings; the reader will find ample details as t[illegible] ble productions in Peacock's Life.—TRANSLATOR.

turn are skimmed over in a few minutes, we may conceive what value would be attached to one who was a true living library, from whom every one could find, at a moment, an exact, precise, substantial answer on all kinds of questions which they could propose to him. Young was much occupied with the fine arts. Many of his memoirs testify the profound knowledge which he had happily acquired of the theory of music. He carried out also to a great extent the talent of executing it; and I believe it is certain that of all known instruments, even including the Scottish bagpipe, only one or two could be named on which he could not play. His taste for painting developed itself during a visit which he paid to Germany. There the magnificent collection at Dresden absorbed his attention entirely; for he aspired not solely to the easy credit of connecting together, without mistake, the name of such or such an artist with such or such a painting; the defects and the characteristic qualities of the greatest masters, their frequent changes of manner, the material objects which they introduced into their works, the modifications which those objects and the colors underwent in progress of time, among other points, occupied him in succession. Young, in one word, studied painting in Saxony as he had before studied languages in his own country, and as he afterward studied the sciences. Everything, in fact, was a subject of meditation and research. The university contemporaries of the illustrious physicist recalled a laughable instance of this trait of his mind. They related that entering his room one day, when for the first time he had taken a lesson in dancing the minuet, at Edinburgh, they found him occupied in tracing out minutely with the rule and compasses the route gone through by the two dancers, and the different improvements of which these figures seemed to him susceptible.

Young borrowed with happy effect from the sect of the Friends, to which he then belonged, the opinion that the intellectual faculties of children differ originally from each other much less than is commonly supposed. "Any man can do what any other man has done," became his favorite maxim. And further, never did he personally himself recoil before trials of any kind to which he wished to subject his system. The first time he mounted a horse in company with the grandson of Mr. Barclay, the horseman who preceded them leaped a high fence. Young wished to imitate him, but he fell at ten paces. He remounted without saying a word, made a second attempt, was again unseated, but this time was not thrown further than on the horse's neck, to which he clung. At the third trial the young learner, as his favorite motto taught, succeeded in executing what another had done before him.* This experiment need not have been referred to here, but that it had been repeated at Edinburgh, and afterward at Göttingen, and carried out to a further extent beyond what might seem credible. In one of these two cities Young soon afterward entered into a trial of skill with a celebrated rope-dancer; in the other, (and in each case the result of a challenge,) he acquired the art of executing feats on horseback with remarkable skill, even in the midst of consummate *artistes*, whose feats of agility attract every evening such numerous crowds to the circus of Franconi. Thus, those who are fond of drawing contrasts may, on the one side, represent to themselves the timid Newton,† never riding in a carriage, so much did the fear of being upset preoccupy him, without holding to

*This anecdote seems at variance with what is stated on the authority of a Cambridge contemporary of Young in Dr. Peacock's Life, (p. 119,) that he only once there attempted to follow the hounds, when a severe fall prevented any further exhibitions of the kind.—TRANSLATOR.

†This practice has been described as that of Newton's, but the motive assigned by Arago is novel.

both the doors with extended arms, and, on the other, his distinguished rival galloping on the backs of two horses with all the confidence of an equestrian by profession.

In England, a physician, if he does not wish to lose the confidence of the public, ought to abstain from occupying himself with any scientific or literary research which may be thought foreign to the art of curing diseases. Young for a long time did homage to this prejudice. His writings appeared under an anonymous veil. This veil, it is true, was very transparent. Two consecutive letters of a certain Latin motto served successively in regular order as the signature to each memoir. But Young communicated the three Latin words to all his friends both in his own country and abroad, without enjoining secrecy on any one.

Besides, who would be ignorant that the distinguished author of the theory of interferences was the foreign secretary of the Royal Society of London; that he gave in the theater of the Royal Institution a course of lectures on mathematical physics; that, associated with Sir H. Davy, he published a journal of the sciences, &c.? And, moreover, we must say that his anonymous disguise was not rigorously observed even in his smaller memoirs; and on important occasions, when, for instance, in 1807, the two volumes in quarto appeared, of 800 or 900 pages each, in which all branches of natural philosophy were treated in a manner so new and profound, the self-love of the author made him forget the interests of the physician, and the name of Young in large letters replaced the two small italics, whose series was then terminated, and which would have figured in a rather ridiculous manner in the title-page of this colossal work.

Young had not then, as a physician, either in London or at Worthing, where he passed the sea-bathing season, any extended practice. The public found him, in fact, too scientific. We must also avow that his public lectures on medicine, those for instance which he delivered at St. George's Hospital, were generally but ill-attended. It has been said, to explain this, that his lectures were too dry, too full of matter, and that they were beyond the apprehension of ordinary understandings. But might not the want of success be rather ascribed to the freedom, not very common, with which Young pointed out the inextricable difficulties which encounter us at every step in the study of the numerous disorders of our frail machine?

Would any one expect at Paris, and especially in an age when every one seeks to attain his end quickly and without labor, that a professor of the faculty would retain many auditors if he were to commence with these words, which I borrow literally from Dr. Young: "No study is so complicated as that of medicine; it exceeds the limits of human intelligence. Those physicians who precipitately go on without trying to comprehend what they observe, are often just as much advanced as those who give themselves up to generalizations hastily made on observations in regard to which all analogy is at fault." And if the professor, continuing in the same style, should add, "In the lottery of medicine the chances of the possessor of ten tickets must evidently be greater than those of the possessor of five," when they believed themselves engaged in a lottery, would those of his auditors whom the first phrase had not driven away be at all disposed to make any great efforts to procure for themselves more tickets, or, to explain the meaning of our professor, the greatest amount of knowledge possible?

In spite of his knowledge, perhaps even from the very cause that it was so extensive, Young was totally wanting in confidence at the bedside of the patient. Then the mischievous effects which might event-

ually result from the action of the medicine, even the most clearly called for, presented themselves in a mass to his mind; seemed to counterbalance the favorable chances which might attend the use of them; and thus threw him into a state of indecision, no doubt very natural, yet on which the public will always put an unfavorable construction. The same timidity showed itself in all the works of Young which treated on medical subjects.* This man, so eminently remarkable for the boldness of his scientific conceptions, gives here no more than a bare enumeration of facts. He seems hardly convinced of the soundness of his thesis, either when he attacks the celebrated Dr. Radcliffe, whose whole secret in the most brilliant and successful practice was, as he has himself said, to employ remedies exactly the reverse of the usual way; or when he combats Dr. Brown, who found himself, as he says, in the disagreeable necessity of recognizing, and that in accordance with the official documents of an hospital, attended by the most eminent physicians, that, on the average, fevers left to their natural course are neither more severe nor of longer duration than those treated by the best methods.

In 1818 Young, having been named secretary to the Board of Longitude, abandoned entirely the practice of medicine to give himself up to the close superintendence of the celebrated periodical work known under the name of the Nautical Almanac. From this date the Journal of the Royal Institution gave every quarter his numerous dissertations on the most important problems of navigation and astronomy. A volume entitled "Illustration of the Mécanique Céleste of Laplace," a scientific discussion on the tides, amply attested that Young did not consider the employment he had accepted as a sinecure. This employment became, nevertheless, to him a source of unceasing disgust. The Nautical Almanac had always been, from its commencement, a work exclusively destined to the service of the navy. Some persons demanded that it ought to be made, besides, a complete astronomical ephemeris. The Board of Longitude, whether right or wrong, not having shown itself a strong partisan of the projected change, found itself suddenly the object of the most violent attacks. The journals of every party, whig or tory, took part in the conflict.

We were no longer to view it as a union of such men as Davy, Wollaston, Young, Herschel, Kater, and Pond, but an assembly of individuals (I quote the words) "who obeyed a Bœotian influence." The Nautical Almanac, hitherto so renowned, was now declared to have become an object of shame to the English nation. If an error of the press was discovered, such as there must be in any collection of figures at all voluminous, the British navy, from the smallest bark up to the colossal three-decker, misled by an incorrect figure, would all together be engulfed in the ocean, &c.

It has been pretended that the principal promoter of these foolish exaggerations did not perceive such foolish errors in the Nautical Almanac until after he had unsuccessfully attempted himself to obtain a place in the Board of Longitude. I know not whether the fact was so. In any case, I would not make myself the echo of the malicious commentaries to which it gave rise. I ought not to forget, in fact, that

*This timidity in medical speculation is entirely borne out by the tenor of Young's intellectual character, as exhibited in such forcible lineaments in the portrait presented to us by Dr. Peacock. His mind was essentially cast in a matter-of-fact, positive, demonstrative mold; hence all subjects of abstract or doubtful inquiry, in which probabilities alone could be estimated, or when the conclusions were to be the result of moral discrimination, were utterly unsuited to him. His medical character has been viewed, however, in a much higher light by Dr. Peacock, who has sought to combat the unfavorable impressions here advanced. (See especially pp. 213, 222.)—TRANSLATOR.

for many years past that member of the Royal Society to whom I allude has nobly devoted a part of his large fortune to the advancement of science. This commendable astronomer, like all men of science whose thoughts are concentrated on one sole object, fell into the error, which I do not pretend to excuse, of measuring through a magnifying-glass the importance of the projects he had conceived. But that with which, above all, he must be reproached is, that he did not foresee that the hyperbolic language of his attacks would be taken literally; that he forgot that at all epochs and in all countries there are a great number of persons who, having nothing to console them for their littleness, seize as a prey on all occasions of scandal, and, under the mask of zeal for the public good, enjoy the delight of being ignoble defamers of those of their contemporaries whose success has been proclaimed by fame. In Rome, he whose office it was to insult the triumphant conqueror was altogether a slave; in London it was a member of the House of Commons from whom the men of science received a cruel affront. An orator notorious for his prejudices, but who had hitherto vented his bitterness only against productions of French origin, attacked the most celebrated names in England, and retailed against them, in open Parliament, puerile accusations with a laughable gravity. Ministers, whose eloquence was exercised for hours on the privileges of a rotten borough, did not pronounce a single word in favor of genius. The Board of Longitude was suppressed without opposition. The next day, it is true, the wants of an innumerable marine service made their imperative voice heard, and one of the men of science who had been displaced, the former secretary of the board, Dr. Young, found himself recalled to his old labors. Paltry reparation! Would the man of science feel less the separation from his illustrious colleagues? Would the man of feeling less perceive that the noble fruits of human intellect were subjected to tariff by the representatives of the country, in pounds, shillings, and pence, like sugar, pepper, or cinnamon?

The health of our colleague, which had already become somewhat precarious, declined from this sad epoch with fearful rapidity. Skillful physicians, by whom he was attended, soon lost hope. Young himself had a consciousness that his end was approaching, and saw it come with an admirable calmness. Until his last hour he occupied himself without intermission on an Egyptian dictionary then in the press, and which was not published till after his death. When his powers did not permit him any longer to sit up or to employ a pen, he corrected the proofs with a pencil. One of the last acts of his life was to exact the suppression of a small publication written with talent by a friendly hand, and directed against all those who had contributed to the destruction of the Board of Longitude.* Young died surrounded by a family by whom

* The whole account of the transactions connected with the abolition of the Board of Longitude must be received with some qualification. Arago writes on the subject in his usual vehement tone, and in the feeling in which the whole affair would naturally be viewed by a foreigner perhaps not intimately acquainted with the minute points of the case, and the somewhat different relative position occupied by the parties in England to that in which they might stand in France. It may be right very briefly to point out a few particulars in the case, which are necessary for forming a correct impression of it. The Board of Longitude, originally instituted, as its name implied, for one specific object, which it was considered had been sufficiently attained, was, in 1818, remodeled by act of Parliament, when Dr. Young was appointed secretary to the board and superintendent of the Nautical Almanac. The late Mr. F. Baily, whose eminence in astronomical science may perhaps be dated from that event, strongly pointed out the numerous defects of the Nautical Almanac. This led to some controversy of rather a sharp nature between himself and Dr. Young, who defended the existing system. Other astronomers joined in the desire for these and even more

he was adored, May 10, 1829, barely at the age of fifty-six. Examination showed that he suffered from ossification of the aorta.

I have not dwelt too long on the task imposed on me if I have brought out, as I wished to do, the importance and novelty of the admirable law

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extensive improvements, all which (with one slight concession) were steadily opposed by Dr. Young. Among these advocates for reform were several members of the board itself, who urged them at its meetings. There was also a very prevalent impression, even among its own members, that the board was not well constituted, and might have been capable of much better service to the nation if its functions were less restricted and the selection of its members placed on a better footing. In other quarters impressions unfavorable to its utility were prevalent, and it can hardly be matter of surprise that, when the board was itself divided in opinion, the public or the legislature should entertain doubts of its utility, or even hostile feelings toward it. What were the precise notions of the government, or the machinations by which they were influenced, it is impossible to say; but it is certain that, in 1828, chiefly through the influence of Mr. Croker, its dissolution was determined upon and carried by act of Parliament without any opposition being attempted. Instead, however, of an enlarged board, with increased powers, three scientific advisers of the admiralty were appointed, of whom Dr. Young was one, retaining the superintendence of the Nautical Almanac—a system which has been since remodeled; in accordance with the report of a committee appointed out of the Astronomical Society.

Dr. Young appears all along to have been affected only by the personal acrimony of some of the attacks upon himself in relation to the editorship of the Nautical Almanac, and not at all by any feeling for the Board of Longitude, as Arago would regard it. That board, as already observed, was divided against itself, and it therefore fell. It was never upheld on the only right ground. Neither the board nor the friends of science sufficiently urged the strong and irresistible claims which they might have preferred to the government of the country, that "a council of science," with extended powers, properly selected and adequately remunerated, would be the appropriate adjunct of the government of a country all whose resources are so powerfully developed in exclusive dependence on the applications of science.

The government would thus have had the means of sound scientific advice constantly at hand, of which experience proves they are in daily want on every emergency, and which they obtain by asking the gratuitous services of men of science, and the Crown would have possessed the means of making a graceful acknowledgment of the services, and paying a just tribute to the genius of men devoted to the higher branches of the abstract sciences, which are of a nature incapable of themselves of affording any kind of remuneration, or, in the ordinary course, leading to any of those honors or preferments which await eminence in other professions.—TRANSLATOR.

The reader may be referred, for details of the questions here considered, to the following documents:

1. "Astronomical Tables and Remarks for 1822; published December, 1821," by F. Baily, esq., with "Remarks on the present defective state of the Nautical Almanac."

2. A reply to these remarks appeared in Mr. Brande's Quarterly Journal of Science, April, 1822. (Attributed to Dr. Young.)

3. Practical observations on the Nautical Almanac, &c., by James South, F. R. S., 1822.

4. Reply to a letter in the Morning Chronicle relative to the government and astronomical science, &c., by the same. 1829.

5. Refutation of misstatements, &c., in a paper presented to the admiralty by Dr. T. Young, and printed by order of the House of Commons, by the same. 1829.

6. Further remarks on the present defective state of the Nautical Almanac, &c., by F. Baily, esq., F. R. S., &c. 1829.

7. Report of the committee of the Astronomical Society relative to the improvement of the Nautical Almanac, adopted by the council of the society, and approved and ordered to be carried into effect by the lords commissioners of the admiralty, 1830. (Memoirs of the Astronomical Society, vol. iv, p. 447.)

8. A motion was made in the House of Commons February 23, 1829, for certain returns respecting the Board of Longitude and the Nautical Almanac, &c. The returns were made and printed, consisting of: 1. A memorandum of a statement made to the chancellor of the exchequer for reforming the Nautical Almanac and establishment of a new Board of Longitude. 2. A paper read at the board by J. Herschel, esq. 3. A report on a memorandum, &c., by Thomas Young, M. D. In the last, Dr. Young makes answer to what he considers objections raised in the "Memorandum," and also replies to those of Mr. Baily and Mr. South. Sir J. South's pamphlet contains the Memorandum, the objections raised or inferred by Dr. Young, his replies to them; all which are severely criticised. At page 60 is a curious account of some discussions at Sir H. Davy's *soiree*, between Sir J. South and Dr. Young.

of interferences. Young is now placed before your eyes as one of the most illustrious men of science, in whom England may justly take pride. Your thoughts, anticipating my words, may perhaps perceive already, in the recital of the just honors shown to the author of so beautiful a discovery, the peroration of this historical notice. These anticipations, I regret to say, will not be realized. The death of Young has in his own country created very little sensation. The doors of Westminster* Abbey, so easily accessible to titled mediocrity, remained shut upon a man of genius, who was not even a baronet. It was in the village of Farnborough, in the modest tomb of the family of his wife, that the remains of Thomas Young were deposited. The indifference of the English nation for those scientific labors which ought to add so much to its glory is a rare anomaly, of which it would be curious to trace the causes. I should be wanting in frankness, I should be the panegyrist, not the historian, if I did not avow that, in general, Young did not sufficiently accommodate himself to the capacity of his readers; that the greater part of the writings for which the sciences are indebted to him are justly chargeable with a certain obscurity. But the neglect to which they were long consigned did not depend solely on this cause.

The exact sciences have an advantage over the works of art or imagination which has often been pointed out. The truths of which they consist remain constant through ages without suffering in any respect from the caprices of fashion or the decline of taste; but thus, when once these researches rise into more elevated regions of thought, on how many competent judges of their merits can we reckon? When Richelieu let loose against the great Corneille a crowd of that class of men whom envy of the merit of others renders furious, the Parisians vehemently hissed the partisans of the despot cardinal, and applauded the poet. This reparation is denied to the geometer, the astronomer, or the physicist who cultivates the highest parts of science. Those who even competently appreciate them throughout the whole extent of Europe never rise above the number of eight or ten. Imagine these unjust, indifferent, or even jealous, (for I suppose that may sometimes be the case,) and the public, reduced to believe on hearsay, would be ignorant that D'Alembert had connected the great phenomenon of precession of equinoxes with the principle of universal gravitation; that Lagrange had arrived at the discovery of the physical cause of the libration of the moon; that since the researches of Laplace, the acceleration of the motion of that luminary is found to be connected with a particular change in the form of the earth's orbit, &c. The journals of science, when they are edited by men of recognized merit, thus acquire, on certain subjects, an influence which sometimes becomes fatal. It is thus, I conceive, that we may describe the influence which the Edinburgh Review has sometimes exercised. Among the contributors to that celebrated journal at its commencement, a young writer was eminently distinguished, in whom the discoveries of Newton had inspired an ardent admiration. This sentiment, so natural, so legitimate, unfortunately led him to misconceive the plausible, ingenious, and fertile character of the doctrine of interferences. The author of this theory had not, perhaps, always taken care to clothe his decisions, his statements, his critiques, with those more polished forms of expression the claims of which ought never to

* The frequenters of Poet's Corner need not be reminded that literature and science are not excluded from their share of funereal honors in Westminster Abbey. M. Arago here, as in some other passages, may naturally be a little incorrect in referring to national usages. The delay which occurred in regard to Young's monument is, however, not fully explained by Dean Peacock. (See Life of Young, p. 465.)—TRANSLATOR.

be neglected, and which, moreover, became a matter of imperative duty when the question referred to the immortal author of the Natural Philosophy,* (the *Principia?*) The penalty of retaliation was applied to him

*It seems impossible to make this sentence intelligible, unless we suppose the "immortal author" spoken of to be Newton, and by consequence that the title *Natural Philosophy* was a slip of the writer's pen for *Principia*. Yet the supposition that the hostility of the Edinburgh Review was at all called forth by any want of courtesy toward Newton in the writings of Young is wholly unsupported by anything in Young's papers, in which he cites the views of Newton with the greatest respect.—TRANSLATOR.

Newton's support of the emission theory of light.—The authority of names can never be of any avail to the truly inductive philosopher; his motto is emphatically "*nullius in verba*." But there has been always a propensity among writers on the subject to dwell on such authority, and to array great names on either side of any of those controverted points which have divided the scientific world. Perhaps, where the question is purely one of opinion, and refers simply to hypotheses upheld for what they are worth as such, the weight of a name may not be unworthy of due estimation: great experience and high genius may add value to a pure *hypothesis*, though it could not to a positive *conclusion*. In regard to theories of light this has been conspicuously exemplified, and during a long continuance of controversial discussion it has been a matter of triumph to the opponents of the undulatory theory that the authority of Newton is on their side. And even Arago, as well as some other supporters of it, have spoken as if regretting that they were thus constrained to put themselves in antagonism to Newton. They have pictured two rival theories, the one headed by Newton and supported by Laplace, Biot, Brewster, and Potter; the other upheld in opposition to them by Huyghens, Hooke, Euler, Fresnel, Young, Airy, and all the Cambridge school.

But a very slight inquiry into the real facts entirely dispels this view of the case. In particular, Dr. Young himself, in proposing his theory, so far from opposing the Newtonian views, expressly endeavors to conciliate attention by claiming the weight of Newton's authority *on his own side;* thus, in his paper "On the theory of light and colors," (Phil. Trans., 1801,) he commences by highly extolling the optical researches of Newton, and then observes, "Those who are attached, as they may be, with the greatest justice, to every doctrine which is stamped with the Newtonian approbation, will probably be disposed to bestow on these considerations (*i. e.*, his own views) so much the more of their attention as they shall appear to coincide more nearly with Newton's opinion." He then proceeds to examine in detail a number of passages from Newton's writings, in which the theory of waves is distinctly upheld and even applied with some precision to the explanation of various phenomena of light, illustrated by their analogies to those of sound.

It is perfectly true that Newton. in the actual investigation of several phenomena of light, adopts other hypotheses than those of waves, and chiefly the idea of light (whatever may be its nature) being subject to certain attractions and repulsions, to certain bendings when approaching near the edges of solid bodies, to certain peculiar modifications or changes in its nature recurring periodically at certain minute intervals along the length of a ray, to the idea of a ray having "sides" endued with different properties; in a word, a variety of conceptions which he introduces for the purpose of giving some kind of imaginary physical representation of the *modus operandi* in each of the several curious experimental cases which he had examined. In all these there is no unity or community of principle; there is at least nothing like the spirit of theory, no continual recurrence to one leading idea, no perpetual appeal to any one principle, however imaginary, but an attempt in each isolated case to frame something like an isolated hypothesis to suit it, and in some way to represent its phenomena, though without any attempt to connect them with the others. It may perhaps be said that all these various suppositions agree in supposing light to be material, to be something emitted from the luminous source. But on a closer examination it seems far from certain that even this can be maintained. The only part of these investigations, perhaps, in which anything very positive of this kind is distinctly introduced, is when Newton investigates the laws of refraction on the express supposition of small molecules attracted by the molecules of the medium. But in this instance it has been truly observed that, at the time when Newton wrote, no mathematical method existed by which this kind of action could be reduced to calculation, except those involving the action of attractive force. To give, then, a mathematical theory of ordinary reflection and refraction, he was necessitated to make use of this method. When he came to investigate those more recondite phenomena which he (very appropriately to their *apparent* nature) called "inflection," the idea most naturally and obviously presented was, that some power or influence, analogous to attraction and repulsion, existing in the edge of an opaque body to bend out of their course rays passing very near it, and this might seem to imply the materiality of those rays. A kind of *alternating* action of this sort, which he imagined necessary to account for a part of the effect, would, however, hardly be reconcilable to the idea of direct emission. It would be a difficult matter

with interest; the Edinburgh Review attacked the man of erudition, the writer, the geometer, the experimenter, with a vehemence, with a severity of expression, almost without example in scientific discussion. The public usually keep on their guard when such violent language is addressed to them; but in this instance they adopted, at the first onset, the opinions of the journalist, in which we cannot fairly accuse them of inconsiderateness. The journalist, in fact, was not one of those unfledged critics whose mission is not justified by any previous study of the subject. Several good papers, received by the Royal Society, had attested his mathematical knowledge, and had assigned him a distinguished place among the physicists to whom optical science was indebted; the profession of the bar in London had acknowledged him one of its shining luminaries; the whig section of the House of Commons saw in him an efficient orator, who, in parliamentary struggles, was often the happy antagonist of Canning. This was the future president of the House of Peers—the present lord chancellor.* How could opposition be offered to unjust criticisms proceeding from so high a quarter? I am not ignorant what firmness some minds enjoy in the consciousness of their being in the right, in the certainty that sooner or later truth will triumph; but I know, also, that we shall act wisely in not reckoning too much on such exceptions. Listen, for example, to Galileo himself, repeating in a whisper, after his abjuration, "*E pur si muove!*" and do not seek in these immortal words an augury for the future, for they are but the expression of the cruel vexation which the illustrious old man experienced. Young, also, in writing a few pages which he published as an answer to the Edinburgh Review, showed himself deeply discouraged. The vivacity, the vehemence of his expressions, ill concealed the sentiment which oppressed him. In a word, let us hasten to say that justice, complete justice, was at length rendered to the great physicist. After several years the whole world recognized in him one of the brightest lumi-

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to conceive particles darted through space with such inconceivable velocity as must belong to those of light, and yet stopping to wave about, in and out, as Newton expresses it, "like an eel," close to the edge of a body, by virtue of some mysterious influence which it exercises upon them.

Again: the theory of those alternating states, conditions, or "fits," as he termed them, at such minute intervals along the length of ray, alternately putting it in a state to be reflected, and again to be transmitted by a transparent medium, seem very remote from the idea of a single rectilinear progress of molecules through space following one another at immense intervals of distance, though in inconceivably rapid succession in time. It would be easy to extend such remarks; but it will probably be seen, with sufficient evidence for our present purpose, that neither in profession nor in fact can Newton's name be appealed to as at all an exclusive supporter of the material hypothesis of light, even if in other passages he had not distinctly referred to that of undulations; and of these references a large number are quoted from different portions of his writings by Dr. Young in the paper above cited. In some of these, while he admits the readiness with which the idea of waves represents the phenomena, he yet dwells on certain apparent objections which seemed to invalidate that idea.

Upon the whole, it appears that the name of Newton can in no way be legitimately claimed as a partisan of either theory. Indeed, it is surprising that any claim of the kind could have been set up as regards the emission theory, after his own distinct avowal:

"'Tis true, that from theory I argue the corporeity of light; but I do it without any absolute positiveness, as the word 'perhaps' intimates; and make it at most but a very plausible consequence of the doctrine, and not a fundamental supposition, nor so much as any part of it."—(Phil. Trans., vol. x, 1675, p. 5086.)

While in respect to either hypothesis, it is sufficiently evident to those acquainted with his writings that he never *systematically* upheld either the one or the other; but from time to time, as each particular investigation seemed to require, he adopted the one or the other principle, just as it seemed to give the more ready explanation of the point before him.—TRANSLATOR.

* Lord Brougham, who held that office when this biography was written.

naries of the age. It is from France (and Young took pleasure in himself proclaiming it) that the first sign of this tardy reparation showed itself. I will add that, at an epoch considerably before the doctrine of interferences had made converts either in England or on the Continent, Young found within his own family circle one who comprehended it, and whose assent to it might well console him for the neglect of the public. The distinguished person whom I here point out to the notice of the physicists of Europe will excuse me if I complete this indiscretion by stating the circumstances. In the year 1816 I made a tour in England with my scientific friend, M. Gay-Lussac. Fresnel had just then entered on his scientific career in the most brilliant manner by the publication of his memoir on diffraction. This work, which, in our opinion, contained a capital experiment irreconcilable with the Newtonian theory of light, became naturally the first subject of our discussion with Dr. Young. We were astonished at the numerous qualifications which he put upon our praises of it, until at length he stated to us that the very experiment which we so much commended had been published, so long since as 1807, in his treatise on Natural Philosophy. This assertion did not seem to us well founded. It caused a long and minute discussion. Mrs. Young was present, without appearing to take any part in the conversation; but we imagined that the weak fear of being designated by the ridiculous sobriquet of *bas-bleu* rendered the ladies of England very reserved in the presence of foreigners, and our want of discernment did not strike us till the moment when Mrs. Young quickly quitted her place; we then began to attempt excuses to her husband, until we saw her re-enter the room carrying under her arm a large quarto volume. This was the first volume of the Natural Philosophy. She placed it on the table, and without saying a word opened it at page 787, and pointed with her finger to a diagram in which the curvilinear route of the diffracted bands, on which the discussion turned, was theoretically established.

I trust I shall be pardoned these little details. Too numerous examples may almost have habituated the public to consider destitution, injustice, persecution, and misery as the natural wages of those who devote their vigils to the development of the human mind. Let us not, then, forget to point out the exceptions whenever they present themselves. If we wish that youth should give itself up with ardor to intellectual labors, let us show them that the glory attached to great discoveries allies itself, sometimes at least, with some degree of tranquillity and happiness. Let us even withdraw, if it be possible, from the history of science so many pages which tarnish its glory. Let us try to persuade ourselves that in the dungeons of the inquisitors a friendly voice had caused Galileo to hear some of the delightful expressions which posterity has kept sacred for his memory; that behind the thick walls of the Bastile, Freret might yet have learned from the world of science the glorious rank which it had reserved for him among the men of erudition, whom France honors; that before going to die in a hospital, Borelli had found sometimes in the city of Rome a shelter against the inclemency of the atmosphere, and a little straw on which to lay his head; and, lastly, that the great Kepler had not experienced the sufferings of hunger.

NOTE BY THE AUTHOR.—The journals having done me the honor to mention sometimes the numerous testimonies of good-will and friendship which Lord Brougham had shown me in 1834, as well in Scotland as in Paris, a word or two of explanation here seems indispensable. The *éloge* of Dr. Young was read at a public sitting of the Academy of Sciences, November 26, 1832. At this period I had never had any per-

sonal acquaintance with the writer in the Edinburgh Review, and thus all charge of ingratitude must fall to the ground. But could you not, some might perhaps say, have suppressed entirely, when your paper was going to the press, all that related to so unfortunate a controversy? I could have done so, and in fact the idea had occurred to me; but I soon renounced it. I know too well the elevated feelings of my illustrious friend to fear that he will take offense at my frankness in regard to a question on which I have profound conviction that the great extent of his genius has not preserved him from error. The homage which I render to the noble character of Lord Brougham, in now publishing this passage of the *éloge* of Young without any modification, is, in my mind, sufficiently significant to render it needless to add a word more.

MEMOIR OF AUGUSTE BRAVAIS.*

BY M. ÉLIE DE BEAUMONT,
Perpetual Secretary of the French Academy of Sciences.

[*Translated for the Smithsonian Institution by C. A. Alexander.*]

One of the highest gifts of the human intellect is to lift itself to the contemplation of the future; to enjoy in advance the benefits which it prepares for the after-races of mankind; to feel itself already recompensed for long and laborious efforts by the thought that a measure of glory will, some day, encircle a name which is still unknown.

It is your noble privilege, members of the Academy, to pay this tribute of the future; to discharge by anticipation the debt bequeathed to posterity, especially in the case of those whom an untimely death has precluded from the enjoyment of their success; and when a savant, prematurely snatched away from his studies, leaves works as yet but little known, though well worthy of being so, works deprived of the brilliant retinue with which he would in good time have surrounded them, these are orphans the guardianship of which peculiarly belongs to you. Such are the motives which have determined your administrative committee to call your attention to-day to a colleague who, struck down in your ranks almost at the moment when he had just entered them, will leave in several branches of the sciences ineffaceable traces through the labors by which he had earned your suffrages.

Auguste Bravais was born August 23, 1811, at Annonay, in the department of Ardèche. His paternal family sprang from the neighboring town of Saint-Peray, where it had enjoyed for several centuries the consideration and esteem which have, in all ages, been associated with long traditions of honor and loyalty. His father, born in 1764, had completed his scientific studies at Montpellier, where he had been preparator for the chemical courses of Chaptal, and had received the degree of doctor of medicine in 1790. Devoted to natural history, he had successively solicited permission to take part in the two expeditious sent in 1791 and 1792 in search of La Pérouse, but had been stopped by different obstacles, and finally by the opposition of his family, alarmed at the first symptoms of the Revolution, by which, like so many others, it was severely tried. When tranquillity reappeared Dr. Bravais established himself at Annonay, a small town picturesquely situated at the entrance of one of the gorges of the Vivarais, known for its manufactures of paper and for having been the country of the celebrated Montgolfier. Here he was soon recognized as an excellent practitioner, and for forty years exercised gratuitously the functions of physician of the hospital. With his devotion to the sick and to the welfare of his fellow-citizens was always allied in Dr. Bravais an enthusiastic love of botany. He undertook a flora of the Cevennes and Alps, and maintained a constant correspondence and commerce of exchanges with the most distinguished botanists of Paris and Montpellier. It was in this way that he received

* Read at the annual public sitting of the 6th February, 1865.

one day the seeds of the *Dahlia*, a plant then new to Europe, and to him is due the introduction of that fine flower into the center of France.

Dr. Bravais had become one of the most considerable men of Annonay, when he espoused, early in the century, an estimable member of the ancient and noble family of Thomé, which had given counsellors to the parliaments of Paris and Grenoble and a lieutenant general to the armies of the King. A few years saw him surrounded with a family of four sons and a daughter, of whom the youngest of the sons was our future colleague, Auguste Bravais. Their mother died shortly after the birth of her daughter, and neither she nor the little Auguste could remember having seen her. Feeling the approach of death, the thoughts of Madame Bravais dwelt chiefly on her children, and having long remarked the piety and pure sentiments of one of the female members of her household, she drew from this person a promise not to quit them. Never was confidence better bestowed. The excellent creature remained forty years in the house, and from her the two infants yet in the cradle received, with the maternal care demanded by their age, those first impressions of childhood which are never effaced. The rapid development of their intelligence reflected honor on hers. At the age of three years Auguste could read, without its being well known how he had learned to do so, and there was for him no greater enjoyment than to gather with his sister the flowers, the pebbles, the insects of brilliant colors, which attracted notice in their rambles; these were the toys of their childish years.

They were soon capable of following the excursions of their elder brothers, whom they had seen bringing back every day objects which stimulated their curiosity. When his occupations permitted, Dr. Bravais himself conducted these explorations. It was a touching tableau, that of this young family herborizing, classifying plants, insects, minerals, under the eye and direction of its head, at once father and professor, whose soul, profoundly religious, habitually lifted that of the youthful naturalists to the Author of creation. His mind, at once acute and playful, was well qualified to render attractive the explanations suggested to him by the collections of the day, with which he frequently mingled classic citations suited to stimulate his children in their studies; for it was his good fortune to have himself received, among the Oratorians, a solid instruction which contributed to the happiness of his life and finally conferred consolation on his honored and serene old age.

The memory of this man of worth is still held in veneration at Annonay, where more than one of its workmen may even now be seen instinctively to raise his hat on passing before his uninhabited mansion. His children, while following their different tendencies, preserved the impressions of their first education. Auguste manifested in good season a turn for observation, and a decided inclination for indulging it. When yet a child, he was attentive to atmospheric phenomena. He might have been seen descending of a morning to the terrace, there to observe the sky, the wind, the clouds. Still later, when become a little more learned, he would establish of an evening his observatory on the balcony, and point out to the assembled family a thousand phenomena which without him would have passed unperceived, the effects of certain rays of the setting sun; the moon with the accidents of light which environ it; the rainbows, the *halos*, in which he knew not as yet that he should one day find a title to celebrity.

The paternal residence had for its horizon a mountain of moderate height, yet sufficient to serve, as we say, for a barometer. It is called the *Roche de Vent*. The clouds heaped themselves around it, the snow

left its traces, mists sometimes visited it. It played no indifferent part in this childish existence. Conducted thither by his father and brothers, it became the point to which his yet narrow observations and expeditions were directed, though it required four or five hours to ascend and return. His ambition, however, soared much higher when he saw his brothers return from the Pilat, a mountain well known to naturalists, bringing thence new flowers, unknown insects, and heard them describe the splendors of the sun rising behind Mont Blanc. He was not ten years old, and five or six hours were necessary to reach the summit. Yet, having well pondered his plans, he departs alone one morning, determined that he also would sleep on the mountain top, and collect its plants, its stones, its insects. His absence excited little inquietude at home, for the sagacity with which he was accustomed to explore the complicated recesses of the mountains of the Vivarais was well known; and, in fact, he returned safely the next morning with the objects which he had coveted, having drunk at the source of the Gier and seen the sun rise behind Mont Blanc, throwing into magnificent perspective the long chain of the Alps. Here we see the embryo adventurer destined one day to climb the perilous heights of Mont Blanc itself.

Habits of meditation early announced the aptness which he was to exert at a later period in the advancement of science. Those who frequented the paternal mansion remember having often met a child apparently absorbed in profound reflection, and who, to the inquiries which he excited, would naively answer: *I am thinking.* And, indeed, so active and fruitful was this habit of thought that at the age of fourteen he had completed all the classical and literary courses of the College of Annonay. His father now thought proper to send him to Paris, that he might devote a year to rhetoric and another to philosophy in the College of Stanislas. The young Auguste carried thither habits of obedience and modesty which did not prevent him to be an indocile pupil. He pursued with the utmost exactness the prescribed studies, and succeeded in acquiring that pure, clear, and precise style which is the usual index of a good education; but he did not evince for classical studies the ardor for which the premiums at the end of the year are reserved. His predilections were directed elsewhere. Some books, hidden at the bottom of his trunk, had escaped notice. These were *works on mathematics;* and these he found means of studying at night. He solved problems and wrote letters full of intelligence to M. Reynaud, the modest and learned professor of the College of Annonay, who had already given him lessons in arithmetic and geometry.

On his return from Paris he was again placed under the charge of M. Reynaud, of whom he had become rather the friend than pupil, and as he had been destined by his father for the Polytechnic School, a certain insight into all that is required for admission was afforded him by the professor in the course of a single year. In 1828, therefore, he ventured to present himself at Nismes for examination; but his preparation had been too rapid, and he was not received. Happily for himself and for science, the boundaries of which it was his fortune afterwards to extend, he had fallen into the hands of a discriminative examiner, M. Bourdon, who, while verifying the insufficiency of his studies, recognized the aptitude of his genius. This excellent man, to whom many among us besides owe a debt of gratitude, reflected on the future of this youthful candidate whom he was obliged to reject, and, with the ingenuous earnestness which he more than once displayed in behalf of students of whom he augured favorably, pleaded with the father of Auguste, and succeeded in persuading him that the career of the unsuccessful appli-

cant still lay in the polytechnic line. After this Dr. Bravais no longer hesitated, but sent his son anew to Paris, where he was placed in the institution of M. Barbet, then distinguished as one of the best seminaries of preparation for the Polytechnic School.

Auguste Bravais pursued at the College of St. Louis, under M. Delille, the course of special mathematics. At the end of the year he obtained at the general competition the first prize of mathematics, and was received at the Polytechnic School as number two of the list. On passing into the first division, after a year's study, he was classed as first, and at his exit made choice, with his father's approbation, of the marine service. *The sea!* How many opportunities did that name suggest of seeing distant shores, of studying nature in its different aspects, and of continuing, with enlarged knowledge, the studies which had formed the delight of a happy childhood.

He embarked in January, 1832, on board the Finistère, which then navigated the waters of the Mediterranean; but he soon passed to the brig Loiret, commanded by M. Bérard, whom we have since counted among the correspondents of our section of geography, and who was at that time charged with the exploration of the coasts of Algeria. The Loiret, on board of which was also M. De Tessan, hydrographical engineer, and now our colleague, was employed two summers in making the coast survey of our African possessions, and the work was completed when the vessel re-entered the port of Toulon, October 25, 1833. The minister of marine, with a sagacity which does honor to his memory, had composed of future academicians the official staff of a vessel charged with a scientific mission, and the commander, M. Bérard, in his excellent work, *Description Nautique des Côtes de l'Algérie*, took occasion to convey to his assistants, and expressly to M. Bravais, his warm acknowledgments of the important share which they had borne in the common labor.

The Loiret was next employed in maintaining the communications between Algiers, Bona, and Oran, being armed on account of the hostile disposition of the inhabitants of the shores. In these incessant passages from one extremity of the Algerine coast to the other, it was necessary to make many different ports, and M. Bravais, who had been named lieutenant in 1834, lost none of these invaluable opportunities of satisfying his passion for natural history. A flora and fauna, different from those of the Cevennes, offered a multitude of objects calculated to pique his curiosity. Magnificent collections of plants, insects, crustacea, fish, terrestrial or marine mollusks, rewarded his activity. Of these he made frequent remittances to Annonay, and sometimes carried thither in person the fruits of his researches, for, since leaving the Polytechnic School, he invariably passed there all the vacations and furloughs he could obtain. On these occasions of a return to his native place, he never failed to revisit his dear mountains, Pilat and Roche de Vent, and resumed, though on a wider scale, the walks and herborizations which had formed of old the happiness of the Bravais family. Knapsack on his back, the young mariner then made long excursions, accompanied by his brother nearest in age to himself, the Abbé Camille Bravais, now professor of natural history at the College of Annonay, and keeper of the museum of that city, composed in great part of his own gifts and those of his family.

But it was with his eldest brother, Dr. Louis Bravais, that our future colleague devoted himself to the more profound investigations of botany. At the beginning of the year 1835, the two brothers united in presenting to the Academy a memoir entitled: *Essai géométrique sur la symétrie des feuilles curvisériées et rectisériées*, (Geometrical essay on cur-

viserial and rectiserial leaves.) This memoir had nothing in common with the ordinary labors of botany relating to the description of species, or to botanical geography. As little was it a memoir on vegetable physiology in the usual acceptation of the word. It was a work of a wholly special and original character on the relations of symmetry, presented by the insertions, at different points of the stem, of the leaves and organs which spring from it. This subject, although MM. Bravais had no knowledge of the fact, had shortly before been the subject of a memoir published by two distinguished botanists, MM. Schimper and Alexander Braun, who had pointed out its importance, and had arrived at some very curious results. M. Adolph Brongniart, however, in the report which he made to the Academy in 1837, pronounced that MM. Louis and Auguste Bravais had brought more precision to the study of the numerous facts which they had collected than had been before exemplified. The subject, moreover, could not be completely elucidated without a profound knowledge of the helix and of the different spirals in which the insertions of the leaves are aligned with so remarkable a regularity, and without a singular dexterity in the management of continuous fractions, recurrent series, and other mathematical combinations of a delicate nature. M. Auguste Bravais had employed them, with the elegant simplicity which is always the stamp of an accomplished mathematician, for expressing the relations of position of the leaves with one another, and for arriving in a clear and precise manner at consequences which could not otherwise be obtained except by long and tedious tentatives. These deductions have brought to light, in a degree but little suspected by many, a regularity of arrangement in the organs of vegetables, which, without being precisely analogous to the laws of crystallography, is equally as precise and admirable.

The brothers still further drew up in common different memoirs on botany, and it was not at Paris only that their labors obtained a deserved success. They equally attracted the attention of botanists in other parts of Europe, and M. De Candolle dedicated to the two authors, under the name of *Bravaisia*, a new species of the family of the Bignoniaceæ. The objects of natural history which M. Auguste Bravais sent from Algeria were also highly appreciated. In 1835 he found on the Island of Rachgoun a serpent which was new to him, the *Amphisbœna cinerea*, and which he transmitted to M. De Blainville, who testified his surprise at the occurrence of such an animal in that country. Other remittances of seeds and living plants, collected in the province of Oran, earned for him letters of thanks from the administration of the Museum of Paris, and warm encouragements to complete the herbal of Desfontaines, and to continue his researches in botany during the voyages it was hoped he would undertake to other regions.

The ardor of the young officer was so much increased by this success as sometimes to make him forget that he was no longer in the peaceable mountains of the Ardèche or of Dauphiny; it drew upon him, on several occasions, the kindly reproaches of his superiors for rashness. But these reproaches were changed into felicitations when, August 12, 1836, at the head of thirty-seven marines, he extricated the commandant and surgeon of the Loiret, surrounded, during a hunting excursion, by the troops of the Emir.

Unluckily, he did not arrive in time to rescue another officer, whom the Arabs had already carried off. But from the point where he then stood M. De France had witnessed the combat, which he describes in his interesting account of the prisoners of Abd-el-Kader. "I will not conclude," he says, "without speaking of the bravery, the coolness, and

address of my colleague, M. Bravais, lieutenant of the frigate. This courageous friend commanded the sailors who flew to our succor; he disposed his troop so skillfully, and fell so vigorously on the enemy, that he forced them to fly precipitately, and, if conduct and intrepidity could have saved me, undoubtedly the conduct and intrepidity of M. Bravais would have secured my release."

The commandant, being wounded in the arm, could not write, and as the first lieutenant was prisoner, the duty of making the report upon the fight, in which two sailors had been slain, devolved on M. Bravais. In drawing up this paper he avoided, as far as possible, under the impulse of his habitual modesty, all mention of himself; hence, while the minister of marine bestowed praise upon the Loiret, the author of the report received no decoration, as all around him would have wished. Yet, in the eyes of those who knew all the details of the affair, the undesigned omission of the minister reflected more honor on the young officer than the star itself of the order would have conferred. He received that distinction, however, on another occasion, and for services of a wholly different character.

Nature had largely endowed M. Bravais. With the brilliant officer and zealous naturalist there was united in him, according to the expression of M. Cauchy, assuredly a competent judge in such matters, the true geometer. The former student of the College of Stanislas, who, in pursuing his course of rhetoric and philosophy, passed the night in studying books of mathematics, had resumed, on board the Loiret, analogous habits. With the consent of the superior officers, by whom he was rightly appreciated, his comrades, themselves highly distinguished, though with a different turn of mind, replaced him on the quarterdeck when his watch recurred, and M. Bravais shut himself up in his cabin, where he spent the night in executing his calculations, or in solving such problems as presented themselves. It was thus that he made the calculations necessary for the reduction of the hydrographic projection of the coasts of Algeria; and thus, likewise, that he composed the mathematical part of the botanical memoir which he published with his brother. Thus, too, a career was eventually opened to him of a special nature, and such as appealed most directly to his natural proclivities.

Among other mathematical labors which M. Bravais had executed on board the Loiret, he had composed two memoirs, one on the *Methods employed in taking bearings under sail*, and the other on the *Equilibrium of floating bodies*. Having obtained leave of absence from the minister of marine, he formed from these memoirs two theses which he sustained before the Faculty of Sciences of Lyons, in consequence of which he was received as *doctor of sciences*. These theses attracted just notice, and the minister subscribed for several copies of the second for the libraries of the ports. In thus acquiring the doctorate of mathematical sciences, M. Bravais was conforming to the friendly advice of M. Poisson, who, after conducting his examination at his exit from the Polytechnic School, had asked him why he did not enter upon the career of science. He still followed that advice in presenting to the Academy several memoirs of analysis and geometry, upon which MM. Poisson, Sturm, and Savary, made favorable reports.

From this period the minister of marine chose that M. Bravais should be released from the clandestine pursuit of science, and assigned him service in a mission purely scientific. He attached him to the Scientific Commission of the North, which was under the conduct of M. Gaimard, and of which M. Victor Lottin, lieutenant, had for several years formed a part. The commission had been inaugurated under melancholy cir-

cumstances. M. De Blosseville, already celebrated for two important scientific voyages, had received, in 1833, the command of the brig La Lilloise, charged with the superintendence of the fishery in the seas of Iceland, and was accompanied, as second in command, by M. LePeletier d'Aunay. Both these young officers were animated by an ardent zeal for discovery, and had promised to effect for the advancement of science all that was compatible with the objects of their official mission. After a thorough exploration of the coasts of Iceland, they determined to reconnoiter the east coast of Greenland, which had been blockaded by ice for centuries. On a first attempt they penetrated, July 29, in the midst of broken ice, to a distance of about twenty-four leagues from Greenland. They could already take the bearings of the mountains, but their vessel, whose construction was not suitable for an enterprise of this sort, having undergone great damage from the floating ice, they had been constrained to disengage themselves with a view to repairs, while decided on making afterward a new attempt. There was reason to suppose that, in fact, they had become a second time entangled in the ice toward the end of August. From the 25th none of the fishing barks had seen the Lilloise.

Much solicitude had been naturally excited during the ensuing winter for the fate of the expedition, and in the spring of 1834 a vessel was sent in search, whose return without success afforded only new grounds for anxiety. In 1835 the attempt was renewed, and the corvette La Recherche, commanded by M. Tréhouart, was dispatched on a similar mission. M. Gaimard, who six years before had taken an active part in the discovery, on the reefs of Vanikoro, of the remains of La Pérouse's expedition, generously proffered his services to co-operate in the search for M. De Blosseville. Desiring at the same time that the exploration should subserve the interests of science as well as of humanity, he associated with himself several distinguished savants, artists, and men of letters. Such was the nucleus of the Scientific Commission of the North.

All efforts to discover traces of the missing vessel were fruitless; but the scientific commission having collected in Iceland the elements of a magnificent work, the design was embraced of exploring also Spitzbergen and Lapland, and of leaving a part of the scientific body to winter in the latter country, in order to make observations in physics and meteorology. It was determined to increase the number of savants who composed the commission, and M. Martins, one of our best botanists and a distinguished meteorologist, was added to it, together with M. Bravais and several learned Scandinavians. Instructions were asked of the Academy of Sciences, and their preparation was confided to a special commission, whose recommendations were adopted in the sitting of April 23, 1838.

The Recherche was equipped anew, and, under the command of M. Fabvre, left the port of Havre June 13, 1838, bearing the greater part of the members of the commission and all the material necessary for their operations. After touching at Drontheim, the ancient capital of Norway, where she received the Swedish, Norwegian and Danish savants designated by their respective governments, and at Hammerfest, where she landed the stores provided for wintering, the Recherche turned her head toward Spitzbergen and moored, July 25, in the roads of Bell Sound, on the western coast of that group of islands, in 70° 30′ north latitude. The savants and officers of marine immediately addressed themselves to their work. Astronomy, physics, meteorology; the movements and temperature of the sea; the vast glaciers descending

from the tops of the mountains to the bay; the geological constitution of those naked and declivitous mountains; the scanty traces of vegetation, very different from that of Algeria, stretched at their foot along the beach, were the subjects of indefatigable study. M. Bravais, habituated from childhood to climbing rocks, was the first to reach the summit of a peak of difficult access, on which the commission conferred his name. The officers of the vessel constructed a detailed plan of the Bay of Bell Sound, in concert with MM. Lottin and Bravais, who determined the azimuth of the bay, the heighth of the mountains, and the declination of the magnetic needle.

But summer is of short duration in those high latitudes. On August 5, the commandant judged proper to give the signal of departure, and the Recherche again came to anchor, on the 12th, in the port of Hammerfest. Careful observations of the temperature of the waters of the sea at different depths were made during the passage by MM. Bravais and Martins, the former of whom, with Professor Siljeström, Swedish physicist, Professor Lilliehöök, Norwegian physicist and astronomer, and M. Bevalet, draughtsman, landed at Hammerfest to winter in Lapland. The corvette returned to Brest.

The climate of the western coasts of Norway and of the coasts of Lapland is of a remarkable mildness in comparison with that of other points of the globe situated in the same latitude. The tepid waters of the Gulf of Mexico, borne by the ocean current, known as the Gulf Stream, diffuse a perpetual warmth and produce there a wholly exceptional temperature. From this it results that the deep arms of the sea which, under the name of *fiords*, penetrate these singularly indented coasts, are scarcely ever obstructed by ice. Navigation, instead of being suspended for several months, as in the White Sea and the Baltic, is there generally open; and this circumstance gives to the capacious and excellent ports of the fiords of Lapland a certain strategic importance, calculated to enhance the scientific interest which the exceptional climate would of itself inspire. But from its comparatively high temperature the northern part of the Atlantic Ocean is enveloped, during winter, in almost permanent fogs, whose density is sufficient to shut out a view of the heavens. The port of Hammerfest being too near the sea and exposed to this disadvantage, our physicists chose for their winter station the village of Bossekop, situated on a narrow shelf at the extreme point of the Altenfiord, an arm of the sea which penetrates the land to the distance of seventy kilometres, whence it results that the climate is there colder and the sky more frequently clear than on the shores of the ocean. At this place the four physicists established, September 1, the numerous instruments, telescopes, theodolites, gigantic compasses, barometers, thermometers, actinometers, pyrheliometers, &c., which had been landed from the corvette. These instruments had been constructed at Paris by the best artists and on the most perfect models. A small wooden structure, which might be taken down and rebuilt elsewhere, formed the astronomical observatory, while five other cabins served as meteorological and magnetical observatories, &c.

Bossekop is situated in 69° 58′ north latitude, and is therefore 3° 25′ beyond the polar circle. The sun does not rise there every day in the year, and on that of the winter solstice, at noon, its center is 3° 25′ below the horizon. After the middle of November its disk is no longer seen entire, the lower part is lost to sight, and the luminary is wholly invisible after the 17th of that month. For some time a crepuscular light illumines, toward mid-day, the southern arc of the horizon, but toward the 21st of December even this glimmer vanishes. It reap-

pears in the beginning of January and increases by degrees. Finally, on the 31st of January, the solar disk begins again to show itself. It projects a first ray, which is hailed by the universal acclamations of the population stationed at windows or on eminences to salute the beneficent orb, whose priceless value is better felt after such an absence. On that day all labor is suspended, felicitations are exchanged, dances express the common joy, pledges are drunk to the resurrection of the sun; it is the time also for settling the bets which have been made on the rate of watches which, not having been regulated for two and a half months, are liable to have become deranged. The sun, after this, rises every day, at first for a few minutes only; but the days gradually lengthen; at the equinox they are equal to the nights; then the nights grow shorter, and finally extinct; the sun ceases to set, and a continued day of nearly three months forms the compensation for the long night of winter.

The perpetual day of the polar summer has never wanted witnesses; but it needed the resolution inspired by an ardent love of science to await at Bossekop the festival of the resurrection of the sun. More resolution still was needed to undertake the labors which the commission was charged with executing at that point. Notwithstanding the relative moderation of the climate, the thermometer often descends at Bossekop, not, indeed, to 40 or 50 degrees centigrade below zero, as in the north of Asia and America, but, according to the observations of the commission, to 20° or 25°; nor is the depression restricted, as in our climates, to the last hours of the night. Here the night does not terminate, and the diurnal variation of the temperature, evidently independent of the action of the sun, the maximum occurring at 11 o'clock in the morning and the minimum at 6 o'clock in the evening, does not exceed on a mean the tenth of a degree. The wind which at Bossekop is least cold is that of the north, under the influence of the Northern Ocean; while the coldest is that from the south, which bears the frozen air of the Scandinavian Alps. The temperature of the air is at its minimum at the surface of the ground. It rises gradually by some degrees to a height of about one hundred metres, and afterward diminishes agreeably to the usual law. All the elements of the climate were collected by our physicists through observations made uninterruptedly at intervals of two hours, and sometimes hourly, on the barometer, the thermometer, the direction of the wind, the state of the sky, the temperature of the earth at its surface, the magnetic apparatus, &c. All these determinations, inscribed on registers kept constantly and with perfect order, have been published in the great work of the Scientific Commission of the North.

The two marines and two professors divided between them the labor and the watching, the latter being observed with as much regularity as on board a man-of-war; but if an aurora borealis presented an extraordinary brilliancy there was a general turnout; every one was at his post. Some drops of coffee, seasonably taken, dispelled the importunate somnolence of the Lapland night. Of the observers, while a portion noted every five minutes the positions assumed by the magnetic needle under the disturbing influence of the aurora, others, in the open air, recorded, watch in hand, the different phases of the phenomenon and measured the altitudes above the horizon. The adjusting screws of their instruments often became so cold that it was necessary to cover them with cloth, without which precaution their fingers would have adhered to the brass through the sudden congelation of the humidity of the skin.

Independently of the detailed journal of observations of the auroras, printed in the work already referred to, and the splendid plates of the physical atlas, which represent the most remarkable appearances observed by the four physicists, M. Bravais has inserted in the same publication a *Mémoire sur les aurores boréales*, cited by competent judges as more precise than anything heretofore written on the subject. The following rapid summary of the contents of this essay may not be without interest.

When the first doubtful gleams of an aurora begin to diffuse themselves in the sky, there is first perceived at the horizon, a little to the west of north, a dark segment, which, according to the very probable conjectures of M. Bravais, is nothing else than the compact mass of fogs with which the temperate waters of the Polar Sea are almost constantly covered. Above the dark segment gleams of light like those of a conflagration soon make their appearance, simply resulting, perhaps, from the still distant glow of the aurora reflected on the surface of the marine vapors. Some time afterward a luminous arc is traced above the segment, its two extremities resting on the horizon, and its culminating point, which divides it into two equal and symmetrical parts, being situated most frequently in the neighborhood of the magnetic meridian. On an average it falls a little to the west of that meridian, from which it progressively diverges as it becomes more remote from the northern edge of the horizon, especially when, having passed the zenith, it approaches the southern horizon, from which in certain cases it is distant but a few degrees. Sometimes several different arcs show themselves at the same time; very often there are two, more rarely three, but as many as nine have been counted at one time. Their breadth, which at a mean is from seven to eight degrees, occasionally exceeds twenty-five degrees, particularly in the culminant part when it passes near the zenith. Through a combination of measurements this last remark has led to the conclusion that the arcs of the aurora borealis are flattened parallel to the surface of the earth, and thus one of the means proper for furnishing the measure of the height at which these arcs are situated above the surface was suggested to M. Bravais.

The height in question had long before occupied attention, and it had with reason been thought that it might be calculated from the parallax resulting from two observations of the same arc, made simultaneously by two observers placed at a known distance. With a view to this means of determination M. Bravais passed thirteen days of January 1838 at Jupvig, situated fifteen kilometres to the north of Bossekop, in order to observe the auroras from that point, while his colleagues observed them at the same instants of time from their usual station. The forms of a great number of arcs, and especially those of the most regular arcs, were taken with much care by the commission, and M. Bravais, by discussing them, through means of elegant geometric constructions and trigonometrical formulas skillfully reduced to the greatest simplicity, has shown that all these arcs, conformably with the hypothesis of our distinguished correspondent, M. Hansteen, of Christiania, may be considered as the perspectives of circular rings, having their center on the terrestrial radius directed toward the magnetic pole, and their plane perpendicular to that radius. His formulas have given him, for each case, the elevation of the ring above the surface of the earth, and this means of measurement, combined with the two others already indicated, have led him to the conclusion that the arcs of the aurora borealis are situated at an altitude of one hundred to two hundred kilometres, in the region where the shooting stars and bolides become incandescent

and luminous, that is to say, toward the extreme limits of the terrestrial atmosphere, the extent of which had long been supposed to be less considerable.

The color of the arcs is usually of a uniform yellowish white. They are of sufficient transparence to allow the stars to be seen through them, and while the radiance of the most brilliant arcs equals that of stars of the first magnitude, the greater number are only comparable to those of the second, third, and fourth. The position of each arc does not remain invariable during its whole duration; on the contrary, it varies with much rapidity, so as to compel the observer to operate with great quickness, if he would give to the different parts of the same arc positions exactly corresponding as regards one another. In their movements the arcs sometimes approach the zenith and sometimes withdraw from it, whether toward the north or toward the south. Their edge nearest to the horizon is usually the best defined. They have not always regular forms; we see them assume a thousand fantastic configurations, such as that of an undulating scarf, or even of a crook. They sometimes show, especially toward the end, a tendency to become decomposed into short rays in a direction conformable to the width of the arc.

After the arcs, at a rather more advanced hour, appear the rays properly so called, which form the second type to which the gleams of the aurora borealis may be referred. The rays are luminous columns of much greater length than breadth, the prolongation of which on high would terminate at the magnetic zenith, the point of apparent concourse of all the lines parallel to the needle of inclination, and situated, at Bossekop, only 13° toward the south of the astronomical zenith. The brilliancy of the rays is variable like that of the arcs, and generally more vivid. They are susceptible of two movements; one in virtue of which the ray prolongs itself toward the zenith or toward the horizon, the other by which it is displaced laterally and parallel to itself. These movements are sometimes of an excessive rapidity, and it is not rare to see the rays dart their light, with a vibratory movement, toward the zenith, and still more frequently toward the horizon, with extreme vivacity. When these movements are alternate, the ray seems to gambol or dance; hence, the *capræ saltantes* of old authors, the *marionnettes* of the inhabitants of Newfoundland, the *merry dancers* of England. In general the more rapid the movements the more brilliant become the rays. The color of these is usually white or pale yellow, sometimes of a reddish hue. When the vibratory movements of the rays become very precipitate, the brilliant yellow tint is concentrated in their middle part and the opposite extremities take the color of violet-red and green, the red always showing itself on the side to which the ray darts its light. Occasionally the rays unite with one another at the magnetic zenith to form a crown either complete or incomplete; and when, in executing this movement, they lose their usual yellowish tint and glow with an intenser luster, passing into red and green, the crown presents the greatest degree of magnificence which the aurora is capable of displaying. At certain moments the vibratory movements by which the rays are animated change into a sort of general palpitation in which all the gleams of the aurora are confounded, the arcs as well as rays. It is the announcement of a diminution more or less proximate of this splendid meteor.

The refulgence of the aurora borealis might seem to have been given to the polar regions as a compensation for the absence of the sun; for those arctic lights, barely visible two or three times a year on the horizon of Paris, illumine almost every evening the latitudes from which

the star of day is withdrawn. They are no longer observed there during the uninterrupted day of summer; it is at the end of August, and especially at the period of the autumnal equinox, that their number is multiplied in Lapland, and their frequency diminishes at the vernal equinox, and still more toward the end of April. During this interval of more than six months very few nights are destitute of the auroral display.

The apparition of the auroras is therefore subject to the course of the seasons, and it is not less remarkable that even during the hibernal night the hours of their commencement and of their different phases maintain a constant relation to the hour of the passage at the meridian of the sun, which has become invisible. Their appearance always takes place during the hours which correspond to the night of our temperate zones. It is generally between ten and eleven in the evening that they assume the effulgent colors by which some of them are distinguished, and, in all, their greatest brilliancy corresponds to the same period of the night. The meteor usually disappears toward morning.

M. Bravais states that by the light of a brilliant aurora he could read a page printed in small type almost as easily as by the light of the full moon. When the sun no longer rises, the moon, which at its full is in opposition with the sun, is seen almost constantly on the horizon, and the double effulgence of that planet and of the aurora greatly diminishes the obscurity of the polar night. Irregular as are these lights, they suffice to enable the Lapps, the Samoieds, and the Esquimaux to traverse in sleds the limitless snows which cover their country; and when the absence of the sun would tend to dull their minds, the fantastic images presented by a fitful illumination serve to arouse their imagination and afford a pabulum on which it is marvellously exercised.

Notwithstanding the movements with which the arcs and rays of the aurora are endowed, it is evident that they follow the movement of rotation of the earth. The aurora borealis is therefore an atmospheric and not a cosmical phenomenon. Canton, M. Becquerel, and other physicists, have pointed out the resemblance which exists between the violet-red tints of this meteor and those which electricity displays when moving in a vacuum. This circumstance, added to the action of the aurora on the magnetic needle, has led physicists to class it among electric phenomena. M. Bravais gives his adhesion to this opinion, the verification of which has been recently corroborated by a remarkable experiment of our distinguished colleague, M. De La Rive.

After a sojourn of seven months the commission quitted Bossekop, April 1839, and returned to Hammerfest in order to execute sundry labors and await the corvette which was to convey them a second time to Spitzbergen. Vegetation was renewing and developing itself with that astonishing rapidity which, from the commencement of May, an almost continual day gives to it in Lapland. M. Bravais could not resist his passion for herborizing, but unfortunately, in attempting to gather a plant springing from the crevice of a rock, he sustained a violent fall and fractured a knee, so that when the corvette bore off his companions he found himself under the necessity of remaining at Hammerfest until the end of the polar summer should bring back the other members of the commission. Far from being discouraged, however, by so vexatious a mishap, he continued the series of meteorological and magnetic observations, and as soon as the injury permitted him to walk, labored at the completion of two memoirs commenced during his stay at Bossekop, one on the tides, and the other on the lines of the ancient level of the sea.

A sojourn of more than a year had enabled him to perfect his obser-

vation of the tides, and having afterward collated his own measurements with those executed at Reikiavik, in Iceland, and Bell Sound, in Spitzbergen, by MM. Lottin and Laroche-Poncié, and submitted the whole to a thorough discussion, he determined the units of height of tide in several ports of the North Atlantic Ocean. He also calculated for those coasts the value of the semi-diurnal tide and that of the diurnal tide for both the sun and moon. He was struck with the relative importance which the diurnal tide there assumes, and this circumstance, compared with the analogous fact already observed in the Sea of Kamtchatka, led him to infer that the tides of the Atlantic and Pacific mutually influence one another through the Straits of Behring.

The banks of the Altenfiord, in the environs of Bossekop and Hammerfest, as well as at many intermediate localities, present terraces having almost horizontal surfaces, whose regularity recalls the constructions of fortification, though there is nothing artificial about them. Each of these terminates at the foot of the rocks in a line marked by erosions similar to those which the sea produces on its present beach. In each terrace is easily recognized an ancient marine coast, on which the sea has beaten for a long time at a well-defined height. At some points several of these are to be seen, one above the other. M. Bravais occupied himself in a determination of the actual elevation of all these traces of the ancient level of the sea, and here botany has furnished him a useful resource. A marine plant, the *Fucus vesiculosus*, widely dispersed on those coasts, grows upon the rocks only at a certain distance beneath the mean surface of the sea, and forms a yellowish zone, of which the upper limit is well marked and perfectly horizontal. This line supplied the plane to which M. Bravais referred, by precise levelings, the ancient marks of erosion by the sea; and he thus recognized that all these traces of its ancient altitude form five series, more or less distinct, two of which especially are perfectly unbroken; that these last are slightly inclined from the interior of the continent toward the ocean, and that one of them in particular presents two parts of which the inclinations are different. From this we are authorized to conclude that these terraces and the ground which supports them have been *lifted* above the level of the sea; for, if it were the sea which had subsided, each of the two series of terraces would have been perfectly horizontal. The mobility of the solid crust of our globe is thereby fully demonstrated. It might be said that the expression, *firm as a rock*, if taken in too absolute a sense, embodies an illusion, and that there is nothing more unstable in the world than the mean level of the sea.

M. Bravais was occupied with these subjects till the moment when the corvette, returning from Spitzbergen, again arrived at Hammerfest. The members of the commission then separated for the last time, in order to return to their respective countries by different routes. M. Bravais associated himself with M. Martins to return by land, and, still herborizing, traversed, barometer in hand, the plateau of Lapland, where the two travelers determined with precision the altitudes of the upper and lower limits of the different zones of vegetation. In this way they completed, not the Atlantic flora of Desfontaines, as M. Bravais had seemed destined to do, but the admirable labors in botanical geography of Leopold von Buch and the celebrated flora of Wahlemberg.

In the vast forests of Sweden, MM. Martins and Bravais had many opportunities of observing the *Pinus silvestris*, (Scotch fir,) of which those forests are in great part composed, and published at their return a memoir on the growth of that tree, a work which had been recom-

mended by M. De Candolle, and which comprises a mathematical formula for arriving at the probable age of a fir-tree whose diameter is known. At Stockholm they carefully compared their meteorological instruments, and particularly their barometers, with those that were employed for quotidian meteorological observations. This comparison was repeated in all the capitals and great cities through which they passed in returning to France, and their instruments having been compared before their departure, as they were at their return, with those of the Observatory of Paris, a means was thus created of reducing to entire harmony, and of referring in some sort to the same diapason, the meteorological observations which are prosecuted in a large part of Europe.

Having returned to Paris in January 1840, they addressed to M. Arago a detailed letter on the labors of the Commission of the North, which was inserted in the *Comptes-Rendus* of the Academy. Their efforts were justly appreciated and well-earned rewards conferred on them, M. Bravais receiving on his part the decoration of the Legion of Honor, and authority to wear that of the Swedish Order of the Sword. In his capacity of marine officer he was charged by the minister with the duty of collecting, jointly with M. Lottin, all the observations on general physics made by the commission, and superintending the publication. He was permitted at the same time to occupy a chair in one of the faculties of science, then lately created in different cities of France, and was named professor of mathematics applied to astronomy in that of Lyons, of which faculty M. Tabereau, his future brother-in-law, the distinguished founder of the school of La Martinière, was dean. Among the observations made by M. Bravais at the Observatory of Lyons many would deserve to be cited, particularly one on a magnificent appearance of the zodiacal light in the month of February 1842. The researches incident to a preparation for his new functions led also to the composition of an important memoir on the movement of translation of the sun, which he addressed to the Academy of Sciences, in 1843. From the profounder theorems of mechanics on the mutual attractions of the stars and the sun, he here establishes that the proper movement of our total system is towards the star η of the constellation Hercules.

Elected, on his arrival, a member of the Academy of Lyons, M. Bravais bore, with his father and two of his brothers, a very active part in the labors of the scientific congress assembled in that city, and laid before it in detail various important considerations on the meteorology of the south of France. He also contributed efficiently, with MM. Lortet and Fournet, to the establishment of the Hydrometric Society of Lyons, widely known for its important and useful labors. With these occupations was united an assiduous co-operation in the production of a work entitled Patria, which he edited during the three years of his residence at Lyons, in conjunction with MM. Lalanne, Le Pileur, and Martins. This work, undertaken with a view to utility, presents, in a condensed and portable form, a miniature encyclopedia of everything relating to France which it is most desirable to have for immediate reference. The articles in this collection on geography, physics of the soil, as well as many others compiled by M. Bravais, must always be regarded as models of conciseness and lucidity.

But Lyons is not remote from Switzerland and Savoy; the sight of the summits of the Alps, those old friends of his childhood, the sight of the eternal snows, which recalled to him Spitzbergen and Lapland, easily awakened in M. Bravais his instincts as a traveler. In 1841, after the close of his first course, he undertook a journey into Switzerland, and in order to render it subservient to the continuation of his meteorologi-

cal labors, he established himself on the Faulhorn, in company with his elder brother, M. Louis Bravais, and his friend M. Martins.

The Faulhorn is an isolated mountain, elevated 2,680 metres above the sea and placed like a belvidere in face of the highest mountains of the canton of Berne, the Eiger, the Mönch, the Jungfrau. Every summer thousands of tourists ascend this peak, in order to enjoy the magnificent view of the snows and glaciers of the Oberland. The inn established to receive them became the meteorological station of MM. Martins and Bravais. They re-established there the Observatory of Bossekop, and from the 17th of July to the 5th of August made a series of observations similar to those of Lapland, saving the absence of the aurora borealis. Nor was natural history forgotten; familiar with mountains and with the application of physics to the geography of plants, the researches of our savants were rewarded by an ample harvest gathered on the acclivities and in the environs of the Faulhorn. Experiments in physics also, of high interest, were instituted by MM. Bravais and Martins. M. Dumas, our distinguished colleague, had caused to be prepared at Paris several glass balloons provided with taps, in which as complete a vacuum as possible had been established. These balloons were filled with the air which enveloped the summit of the mountain, then closed with the greatest care, and sent back to M. Dumas. Analysis showed that the air inclosed in these balloons contained the same proportions of oxygen and nitrogen with the air taken at Paris; whence it resulted that, contrary to the opinion formerly entertained by Dalton, but controverted by Gay-Lussac and Humboldt, the constituent proportions of the air do not vary with the height. M. Bravais devoted the evenings, when the sky was sufficiently clear, to the study of crepuscular phenomena. His observations, united with those of other meteorologists and submitted to calculation, furnished him a new measure of the height of the atmosphere, equal at least to one hundred kilometres, a result quite approximate to that which had been given him by the auroras of Bossekop.

In 1842 the meeting at the Faulhorn was repeated, and the same series of meteorological observations were continued, but MM. Bravais and Martins applied themselves moreover to researches in physics of a new order. M. Peltier, one of our most distinguished and most exact physicists, snatched away too soon from science, joined them on this occasion and united with M. Bravais in measuring the temperature of ebullition of water under different barometric pressures. The object of these studies was to perfect the tables which serve to determine the elevation above the sea, from the degree of the thermometer at which water enters into ebullition, a method of less inconvenient application than the barometric method.

MM. Bravais and Martins, aided by M. Camille Bravais, who now replaced the elder brother, made also important experiments on the propagation of sound. Mortars were fired on the Faulhorn and on the shore of the Lake of Brienz, 2,041 metres lower down, the flash being visible and the report heard from each station at the other. The perception of the light might be regarded as instantaneous, and by measuring with a seconds watch the retardation of the sound, the velocity of its propagation was determined. It was thus found that, for dry air, at the temperature of melting ice, the velocity of the propagation of sound, whether ascending or descending, is 332 metres 4 centimetres per second. This result accords with that of the celebrated experiments made between Villejuif and Montlhéry, when sound was propagated horizontally.

In 1843 M. Bravais made no excursion; it was for him a year of mourning. His eldest brother, M. Louis Bravais, his coadjutor in the memoir on the symmetrical arrangement of leaves, died at the commencement of summer, after six months of suffering, borne with Christian resignation, in the midst of which he occupied himself, to his last day, with researches in botany. This painful separation slackened but transiently the labors of M. Auguste Bravais. He speedily returned to them with his accustomed ardor, and the year following entered upon a new expedition, the last and perhaps the most remarkable of those which it was given him to accomplish.

The supposition is not improbable that two of our distinguished perpetual secretaries, always pleased at meeting one another on neutral ground, had, about that time, exchanged some words on the subject of M. Bravais. M. Arago had, from the tribune of the Chamber of Deputies, cited him as one of the officers who, by their knowledge, reflected most honor on our marine, even comparing him, in his extemporization, with the geometers of antiquity. M. Villemain, then minister of public instruction, enlightened also by our learned colleague M. Pouillet, had the merit of comprehending the expediency of an adventure which would crown, by the ascent of Mont Blanc, the previous labors of M. Bravais, and drew upon the budget of his department for the expenses of this difficult enterprise.

De Saussure was the first physicist who had made the ascent of Mont Blanc; M. Bravais was the second. He shared this distinction with his friend M. Ch. Martins, and with Dr. Pileur, his collaborator in editing the *Patria.*

It was with no little interest that learned Europe had heard that M. De Saussure, already celebrated for his travels in the Alps, had succeeded in carrying his barometer to the summit of Mont Blanc, and had fixed the height of the mountain at 2,450 toises. He had made at the same time several experiments in physics, which have never ceased to hold an honorable place in all treatises on meteorology. But physics had made great progress in the space of fifty-seven years; it had become time to renew the experiments of De Saussure, and to add new ones, of which no idea could exist in his time. Such was the path which the enlightened liberality of M. Villemain now opened to the hardihood and skill of the three modern physicists.

Having left Paris, July 16, 1844, with a complete series of instruments of better construction than had ever before been employed in a work of this nature, the travelers stopped at Geneva in order to compare them with those which are there daily employed, with a care and dexterity worthy of the country of De Saussure, and arrived at Chamouni, where, in 1787, this last-named savant had been obliged to wait four weeks for weather propitious to his undertaking. M. Bravais and his companions were scarcely more favored. A first and second attempt failed from atmospheric accidents, which were not unattended with danger, but at length they arrived, August 28, for the third time at a wide plateau of snow, 880 metres below the summit of the mountain, where their instruments had been permanently fixed for three weeks, under shelter of a small tent. The night passed cold and calm, and next day, the observations of the morning being completed, the adventurers proceeded, at ten o'clock, to climb to the top of Mont Blanc. This was reached, without any extraordinary difficulties, at forty-five minutes after one o'clock. The wind was blowing with great force from the northwest; the thermometer marked 7° below zero. The sun shone brightly, but vapors veiled the more remote parts of the vast horizon, which extends from

the Côte d'Or to the mountains of Liguria. The circumjacent mountains, on the contrary, were seen with great distinctness. After throwing a glance on this magnificent panorama, MM. Bravais, Martins, and Le Pileur hastened to arrange their instruments—barometer, thermometer, hygrometer, psychrometer, pyrheliometer, actinometer, compass; the instrument for measuring the horizontal magnetic intensity; another for measuring the inclination of the magnetic needle; another for measuring the temperature of ebullition of water; instruments for observing the tints of the sky and transparence of the atmosphere, &c., another for measuring the electric intensity. The genius of De Saussure had suggested a part of the same experiments, but his extemporized instruments were less complicated than those of to-day, whose precision is paid for by the minute precautions which their management exacts.

During the five hours passed on the summit of Mont Blanc, our three physicists had time to derive from their instruments all they were capable of yielding, and to collect a series of measurements which left little to desire. At the approach of evening, the principal experiments in physics having been nearly terminated, M. Bravais established the theodolite, and, assisted by M. Le Pileur, who wrote the angles at his dictation, commenced a survey of the horizon, measuring the angle of depression of each of the mountains which formed it, and the azimuth which expressed the direction in which it was seen. This *circuit of the horizon of Mont Blanc*, which had never before been made, (for De Saussure had confined himself to general remarks,) will remain a valuable monument for geodesy and geology. The work was almost finished, and nothing remained to be taken but the least interesting parts of the panorama, when the process was interrupted by a phenomenon which equally surprised the eight persons (guides and travelers) then assembled on Mont Blanc, because, in nône of the ascents previously made, had any one ventured to remain there till the setting of the sun.

"At forty minutes after six," says M. Bravais, in the little work which contains his *tour d'horizon*, "the sun approaching the moment of its disappearance, we cast our eyes on the side opposite to the luminary, and saw, not without wonder, the shadow of Mont Blanc projected on the snow-covered mountains in the eastern part of our panorama. I took the summit of that shadow with the theodolite, and obtained the depression of — 1°. A minute afterwards it was — 0° 48′, ascending in proportion as the sun declined. We still remained some ten minutes occupied in packing our baggage, and rather anxious to descend on account of the shortness of twilight on high mountains. * * * I have delineated in the panorama the form then presented by the shadow of Mont Blanc. It rose gradually into the atmosphere, as though this were a canvass on which it was just portraying itself. The separation of the shadow and the light was strongly defined in its outlines, and it thus continued to ascend, rising above the mountains of the Valley of Aosta, until it attained the height of 1°, still remaining perfectly visible. The air above the cone of shadow was of that rose-purple tint which, in fine sunsets, is seen to color the western sky, while the border of this tint, along the line of separation, presented a more intense hue of red, contributing greatly to enhance the splendor of the phenomenon.

"Let the mountains of the great Valley of Aosta be now conceived as also simultaneously projecting their shadows into the atmosphere; the outline of their mighty spires distinctly visible; dark, or rather faintly green below, but soaring up into that expanse of rose-colored light from which they were separated by a band of deeper hue; to this be added the precision of the cones of shadow, and especially of the

outline of their crests, and, finally, the effect of the laws of perspective, causing all these lines to converge toward one another and toward the reflected summit of Mont Blanc, where our own shadows might also be supposed to find a place; still but an incomplete idea can be formed of the grandeur of the meteorological phenomenon which, for those few instants, displayed itself before us. It might seem as if some invisible being, seated on a throne edged with fire, received the homage of bright-winged angels who, on their knees, bent in adoration toward him.

"At the view of so much magnificence, our arms and those of our guides remained inactive, and cries of enthusiasm burst from our lips. I have seen the splendid auroras of the north, with their zenith-crowns of variegated and moveable columns, not to be equalled in effect by the richest displays of pyrotechny; but the sight of the shadow of Mont Blanc on the sky appears to me more august by far. After indulging for ten minutes in the contemplation of this spectacle, we were forced again to think of returning. Fortunately, the full moon, rising brightly above the eastern horizon, sufficed for that stage of our journey which conducted us again to our tent, where we arrived after fifty minutes of very rapid descent."

This poetic sally enables us to judge whether the cold of twelve degrees, which then existed on Mont Blanc, and the management of graduated instruments, had chilled the imagination. We may be sure that observers who, at the close of the day, remained accessible to such vivid impressions, had neglected, during its course, nothing which formed the special object of their toilsome and perilous ascent; and we may say, without further commentary, that skillful physicists who have employed fifteen hours of assiduous labor to conduct, on the top of Mont Blanc, the operations of the best instruments known, who, moreover, have occupied four days in following their action on the plateau near the summit, could not fail to have put us in possession of scientific documents of high value, before which a multitude of doubts and uncertainties must disappear.

Having completed, at their tent on the grand plateau, the four days of observation, the travelers descended, September 1, to Chamouni. Here they rejoined M. Camille Bravais, who had been meanwhile engaged in making, every two hours, corresponding observations at the same point where M. Theodore de Saussure, since so celebrated for his investigations in vegetable physiology, had co-operated in like manner in the labors of his distinguished father, while the latter was operating on Mont Blanc. Nor were others indifferent to the issue of the ascent. For a month the father and sister of M. Bravais had gone, every day, to seat themselves at a spot, in the entrance of the Vale of Annonay, whence Mont Blanc and the snowy crests of the Alps may be seen, and whence he had himself in childhood often contemplated them. They had not failed to be there on the 29th of August, but the zone of vapors which, from Mont Blanc, obscured the plains, hid everything from their view. The same disappointment existed at Lyons. With the best telescopes the adventurers could not be perceived on the top of the great mountain, and the preparations made by learned colleagues, MM. Tabareau, Fournet, Lortet, and other eminent physicists, with a view to coöperate in the enterprise by their own observations, remained for the most part unfruitful.

The professor of astronomy had secured for himself, through the amenities of intercourse, a large share in the affection of the faculty. Lively, though reflective, in disposition, full of kindness, of delicacy, and disinterestedness, M. Bravais knew how to enjoy the success of

others, and no shade of rivalry ever found access to him. Always disposed to render service and to give counsel, when asked for, he fulfilled his own duties with the most scrupulous exactness. His lectures drew a numerous auditory, for they were enlivened by the associations which the variety of his studies and experiences presented without effort to his mind, and to which his vivid imagination gave an endlessly diversified expression. In spite of the aridity supposed to be inherent in mathematical pursuits, his conversation was picturesque and sportive, and often heightened by sallies in which science allied itself with poetry. It was never without regret, therefore, that his colleagues of Lyons heard him speak of withdrawing. Yet, this M. Bravais was bound to think of, for the publication of the voyage of the Scientific Commission of the North was advancing, and with that would finish the mission with which he had been charged by the minister of marine. To remain at Lyons would have been to renounce his career as an officer in that branch of service, and he sometimes thought of requesting to be sent on some new voyage. Those who justly saw in him the ideal of the scientific traveler could not forbear from encouraging him to do so, but an unforeseen circumstance put an end to these deliberations.

Our distinguished colleague, M. Lamé, had just relinquished the chair of physics in the Polytechnic School to occupy the place of examiner of graduates. The council, with great unanimity, designated M. Bravais to succeed him. The latter, therefore, a naval lieutenant, was nominated to replace M. Lamé, chief engineer of mines, in a school which furnishes as well officers to the marine as engineers to the corps of mines and of civil constructions.

The preparation of a course so high as that with which he was now charged, gave, for some time, a particular direction to the studies of M. Bravais, and he delayed not to publish several excellent memoirs on atmospheric optics and the molecular constitution of bodies. A year after his ascent of Mont Blanc he presented to the Academy a memoir on *the white rainbow*, which completed in a very happy manner one of the most admirable theories of physics.

Until these latter ages mankind had seen in the rainbow a sign of hope, without knowing the causes of its appearance. Theodorich, De Dominis, Descartes, had explained its formation by the refractions and reflections undergone, in drops of rain, by the rays of the sun. Newton had completed this explanation by the consideration of the unequal refrangibility of colors; but none of these eminent physicists, and none of those who after them had been occupied with the details of the phenomenon, had explained in a satisfactory manner the formation of the *white rainbow*, which is sometimes seen to make its appearance on fogs of little elevation and not far remote from the spectator, with a radius sensibly inferior to that of the ordinary rainbow. It was reserved for M. Bravais to demonstrate that if a cloud is formed of small hollow spheres in which the thickness of the watery envelope is comprised between thirty-eight and fifty-five-hundredths of the radius of the internal vacuum, it must form a white luminous arc of thirty-four to forty degrees of radius, and consequently not so large as the ordinary rainbow of the first order, whose radius is 42° 20′. In ordinary clouds the envelope of the globules of vesicular vapor is thinner than that required by the theory of the white rainbow, whence it results that it is not formed. It is only to be seen on heavy fogs attached to the surface of the land or sea. True, this white rainbow is not one of those phenomena which strongly captivate the imagination; but it is enough for the honor of our colleague to remark that all physicists and Newton himself had left

it without explanation. His memoir has filled a gap in the labors of the first masters of science.

The rainbow is not the only phenomenon which describes on the vault of the heavens geometrical figures more or less brilliant, more or less vividly colored. Parhelions and halos, less frequent, but not less striking than the rainbow, are formed under circumstances so visibly different, that far from appearing of good augury, they have been regarded by the amazed populations as signs of divine wrath. Mariotte had proposed to attribute these luminous apparitions to the action exerted on the rays of the sun or moon by the frozen particles which remain, for some time, suspended in the atmosphere before falling in the form of snow or rain. But Huyghens had combated this explanation, and, for more than a century, it had been left in abandonment. Brandes, Young, Galle, Kämtz, and other celebrated physicists, however, had recurred to it with better success. But M. Bravais has removed all doubts by representing by formulas, reduced with the ingenuity of which he possessed the secret to great simplicity, the course of the reflected and refracted rays, and by deducing from their discussion the forms, however strange, of the observed phenomena.

According to the greater or less depression of the temperature of the elevated regions of the atmosphere, the vapor is there condensed into water which gives rain, or into particles of ice which produce snow, sleet, or hail. The ice crystallizes in regular hexagonal prisms, which, in their most elementary form, are terminated by plane faces perpendicular to the axis of the prism. The prism is sometimes much elongated, sometimes, on the contrary, extremely short. In the first case the frozen particles formed in the air are small needles of microscopic diameter; in the second they are small hexagonal or stellate plates, of a thickness hardly measureable. In both cases these little crystals are very light. They dance in the air like those grains of dust which are seen quivering by myriads in a sunbeam. They fall, however, though slowly, in air perfectly calm. Although microscopic, they have forms of the utmost exactness, for the regularity of crystallization is never more admirable than in the smallest particles of matter.

When the frozen particles are acicular prisms, the luminous rays proceeding from the sun or the moon, in being refracted across two faces not contiguous of the prism, under the angle of minimum deviation, are broken and pursue their route, by making with their first direction an angle of about 22°. In this case, if the small prisms quiver in the air, a colored arc is produced comparable to a rainbow, but of 22° only of radius, of which the luminous body occupies the center and in which the red band is situated on the inner side. This is the halo of 22°, the most frequent of all. If the small prisms, or only a part of them, fall gently through tranquil air, and take a vertical position, there is formed, on each side of the sun and at the same height, an image of that body which is called a parhelion, and which is distant from it, very nearly as is the arc of the halo, about 22°. The rays of light which are refracted, at the angle of minimum deviation, across a diedral angle of 90°, like that which results from the rectangular incidence of the faces of the hexagonal prism on its bases, are more strongly deflected than in the preceding case and produce the halo of 46°. If the prisms are vertical, they give rise to horizontal circles, decked with very lively colors, which are tangents to the upper part or to the lower part of the halo of 46°.

When the frozen particles have the form of small, very thin hexagonal plates, the diedral angles of 90°, presented by the outline of their base,

concur in the formation of the halo of 46°; and should their fall through tranquil air render one of their diagonals vertical, the parhelion of 46° and the anthelion make their appearance. The rays reflected, without dispersion of colors, on the vertical faces of the prisms and hexagonal tablets produce the parhelic circle of M. Babinet, which is brilliant but colorless.

Other combinations may be conceived, almost all realized in nature; moreover, the microscopic crystals of ice, besides their principal faces, sometimes present secondary facets, which also give rise to refractions and reflections, the effect of which is to break the ray of light, in each case, under a special angle. The analysis of all the possible cases of this kind, and the complete explanation which results therefrom of all the phenomena observed, even the most singular and most rare, furnished M. Bravais the subject of the consummate memoir which is fresh in the admiration of learned Europe.

Considering the phenomenon under all points of view, M. Bravais completes the study which M. Arago had given to the polarization of light in halos properly so-called, by extending it to all the parts of meteors of this nature.

Equally skilled as an experimenter, and versed in the management of analytic formulas, he conceives an ingenious apparatus which, by the rapid rotation of a transparent prism with vertical axis, represents with much exactness the multitude of needles or vertical flakes of ice suspended in the atmosphere, whose horizontal movement, dispersed in all directions, produces the greatest number of atmospheric illuminations. By means of this new instrument, and of artificial light, we are able to reproduce in a cabinet of physics most of the phenomena of meteorological optics.

In Lapland and on Mont Blanc M. Bravais had had numerous opportunities of observing the crystalline forms of snow. He had often met with admirable crystallizations of congealed water, and had always described them with a peculiar predilection. In his memoir on halos he employs the notations and formulas which represent the crystalline system of the ice, as one perfectly conversant with them and thoroughly master of their principle. But he did not stop there, and his studies eventually extended to the whole science of crystallography.

In his view crystals are *assemblages* of molecules, identical as regards one another, and similarly oriented or arranged, which—being reduced in thought to a single point, their center of gravity—are disposed in rectilinear and parallel rows, in each of which the distance of two points is constant.

The points of an *assemblage* are aligned in *rows*, corresponding to an endless number of different directions; but the knowledge of three rows not parallel and not comprised in the same plane is sufficient completely to determine the *assemblage* of which they form a part. An infinitude of *assemblages* entirely different may be conceived. By a profound mathematical study M. Bravais had succeeded in discovering the degrees of symmetry, more or less great, of which they are susceptible. He finds the *axes* and the *planes of symmetry* which they may present, and establishes that according to the number and arrangement of these *axes* and *planes of symmetry*, the *assemblages* possessing them are divided into *six classes*. By adding to these the *asymmetric* assemblages, in which there exist neither axes nor planes of symmetry, we have seven classes of *assemblages*. Thus are evolved the most simple and general laws of the symmetry observed in crystals, and the adoption, in crystallography, of *seven crystalline systems* is a necessary consequence. Of this Haüy had had an indistinct perception; but he concluded that two

of the systems might be blended in a single one, and after him all crystallographers had admitted *six crystalline systems* only. M. Bravais *demonstrates* that it is necessary to return to the number seven, and this demonstration, accompanied by all the light which results from a geometric analysis so profound as his, is no slight addition to the immortal creation of Haüy. Lagrange and Laplace had followed, in 1784, the lessons of the ingenious investigator of crystals, but had been content with simply admiring them. The grounds of the beautiful science due to his genius had never been studied from so high a point and with so much generality as in the memoir of M. Bravais on the *systems formed by points;* a memoir to which our illustrious Cauchy has, in a remarkable report, given his most unreserved sanction.

You do not expect me, gentlemen, to enter here into the detail of proceedings, though simple, yet rigorous, by which in a second memoir, entitled *Études crystallographiques*, replacing empirical rules by the theorems of geometry, M. Bravais deduced from his fundamental results all the formulas of crystallography with that marvellous facility which denotes almost infallibility in the radical solution of the difficulties of a subject. Being limited as to time I shall restrict myself to the statement that in the second part of this memoir, ceasing to regard the molecules as points and considering them as small bodies, which he calls atomic polyhedrons, he throws light upon the relations which exist between these latter and the various crystalline systems. He reduces to simple laws the phenomenon, until then almost unknown, of the hemihedral, upon which our learned fellow-member, M. Delafosse, in a justly celebrated memoir, has diffused unexpected light. M. Bravais demonstrates that he could exhibit twenty-five cases of hemihedral forms, of which only eleven had before been discovered, though these were for a long time amply sufficient to exercise the sagacity of crystallographers.

Not forgetting dimorphism, one of the claims of Mitscherlich to distinction, nor the curious discoveries previously made by our ingenious fellow-member, M. Pasteur, M. Bravais, in a third memoir, gives the results of his equally successful labors on the peculiar form of crystallization exhibited in a mineral called macle and hémitropes, which had been in their turn a stumbling-block to the crystallographer. About this time he was also at work upon investigations relative to the connection of atmospheric optics and crystallization, as well as composing various memoirs upon subjects entirely different, but relating for the most part to meteorology, some of which are not the less remarkable from being outside of this branch of physical geography.

He was endowed with a remarkable facility for all kinds of intellectual labor, and he possessed the rare faculty of occupying himself at the same time with the most varied subjects: hydrography, navigation, astronomy, atmospheric optics, physics, properly so called, geometry, crystallography, pure analysis, and natural sciences, were at once the subjects of his investigations. It might be said of him, notwithstanding the apparent opposition of words, that the universal was his specialty.

All his memoirs have received honorable notice in our "*Comptes-Rendus*," and met with merited success by their publication in the most esteemed scientific transactions of the day. They continually present ingenious and frequently profound conceptions, which are well worthy of special attention, but which, for want of time, I am not at present able to specify. The works of Bravais, taken in their totality, are of immense extent, and I am forced to limit myself to a sketch of the principal treatise. As an astronomer, called upon to give an abridged idea of the firmament, can on' detail of the stars of the first mag-

nitude, so I must be content merely to mention among the works of M. Bravais those which form his chief claim to the approbation of the Academy.

By his investigations on crystallography he associated his name with that of the immortal Haüy; from his ascension of Mont Blanc he connected it with that of De Saussure; in his work on Lapland he was the worthy continuator of the celebrated voyages of Leopold von Buch, and of the profound studies of Hansteen. His memoirs upon halos, parhelions, and upon the white rainbow, completed in the most happy manner the theories of Mariotte, of Huyghens, and even of Descartes and Newton. After such achievements, gentlemen, the name of M. Bravais could no longer remain separated from those of the members of the Academy. In the beginning of the year 1854, by the death of Admiral Roussin, a place was made vacant in the section of geography and navigation which M. Bravais was elected to fill. You were right in supposing that this was in your ranks the most befitting place for a sailor and a traveler who had enriched by so large and so varied a mass of observations the domain of physical geography.

Admitted to a seat in the Academy, M. Bravais testified his gratitude by his assiduity, by the number and importance of his communications. Still he did not enjoy as he would have done several years previous, the honor, long and ardently desired, which crowned so worthily an extended career of labor illuminated with flashes of genius. He was no longer what he had been; a visible change was wrought upon him. A veil of sadness was thrown over that countenance, marked with openness, modesty, and amiability. At the close of the year 1847 M. Bravais was united in marriage to Mademoiselle Antoinette Moutié, of Paris; and he found in this union all the charms of a new life. His time divided between the pleasures of family intercourse and the continuation of his works, he had never labored with more ardor nor taken a more active part in scientific enterprise. Independently of his innumerable publications, he had assisted in establishing the *Annuaire Météorologique de France*, and was one of the principal founders of the Meteorological Society, which, at its first session, in 1852, elected him its annual president. But the year 1853, which preceded his election to the Academy, was for him one of disastrous auspices. At the commencement of this fatal year he lost his father, the venerable friend who, having been his first teacher, continued deeply interested in his labors, regarding them with tenderness mixed with noble pride. Almost at the same time his only son was taken from him by an epidemic of which the fatal influence was particularly felt at Paris among children. This was a mortal blow, from which he never recovered. Peculiarly susceptible to family affection, which was the charm and support of his life, with his father disappeared the enchantment of his earliest and sweetest remembrances. One brother died soon after; he had lost another ten years previous. With his beloved child vanished forever the joys of paternity—labor still remained for him, and he applied himself without relaxation. He was stimulated by the desire to reply to the kind welcome of the Academy, and by the counsels of his friends, who endeavored to win him by work from the remembrance of his griefs. He finished a number of memoirs containing important results, and evidently went beyond his strength. Unceasing labor soon began to tell upon him. Sleep fled from his eyelids during the night, and overpowered him during the day. This was in accordance with his feelings. He wished, as in his cabin of the Loiret, to consecrate his nights to work; he even desired, as in Lapland, to vanquish sleep by coffee; but his organs no longer retained the flexibility of youth.

Madame Bravais was convinced that labor would be a salutary diversion for her husband, while at the same time she dreaded excessive fatigue. Tenderness came to her aid and prompted her to resort to a plan to avoid this evil. It was a charming and at the same time heart-rending sight to see her as early as four o'clock in the morning assisting at his table; forgetting her own griefs, by turns endeavoring to moderate his ardor, and to raise his waning courage. But the evil continually increased, the work no longer amounted to any thing; memory was at fault; he could no longer recover the ingenious ideas which he had previously remembered without committing them to paper. He wished to put the last touches to a large memoir upon mirage, which would have completed his labors on meteorological optics, and which, with his usual modesty, he pronounced the most imperfect of his works. He corrected it; he curtailed it; he spoiled it, and, alas, finally made the sad discovery that it was impossible for him to complete it. The darkness of the night seemed to shroud the intellect hitherto so active and brilliant; he left the Polytechnic School for ever, and we ceased to see him among us.

A well-known disease developed itself, accompanied with fever and great suffering. He was sustained in this trying period by deep religious sentiments, the unalterable sweetness of his character manifesting itself in a wonderful resignation.

Madame Bravais went with him to Versailles. She obtained quarters at the entrance of the park, and later near the Bois de Vaucresson and of Lamarche, changing her residence as often as was needful, in order to obtain new and picturesque situations. This at first seemed to please him, but at length ceased to produce any effect. He still took quite long walks with his friends, who remained faithful to him in his misfortunes, particularly with Doctor Bérigny, collaborator in the *Annuaire Météorologique*, whose unceasing devotion continued to the end. He retained his strength, and preserved all the sweetness and kind expression of his countenance, but his memory was gone beyond recall. He recognized neither objects nor individuals, perhaps even did not always know distinctly the one who became to him a tender mother, consecrating her life to relieving his sufferings, and administering to his wants.

Some glimpse of light occasionally pierced through this cruel night, and gave rise to hopes which unfortunately were destined soon to vanish. One day he saw, on entering his chamber, his uniform as a marine officer, hanging over a chair; his face brightened, and a tear escaped from his eye. Another day he smiled on receiving a bouquet of wild flowers, which his sister had gathered for him and laid upon his knee. This was the last smile of our fellow-member; he passed away on the 30th of March, 1863.

Madame Bravais only left her pillow to pray near his coffin. The tomb alone separated her from one to whom for seven years she had been as a guardian angel. Having lost all whom she loved on earth, her only son and her husband, she felt as though there was no longer a place for her in the world. She embraced a religious life in a convent belonging to one of the most austere orders, where happily she has found consolation in her devotion and in the assurance which has been given her that the threads which were broken upon earth will be united in Heaven.

Gentlemen, may the honor which you bestow to-day on the remembrance of a dearly beloved husband penetrate into this asylum of grief, and become a balm for a wound which even time will not have power to heal. The voice of the heart is heard under these sacred vaults, where the voice of the world may not penetrate.

MEMOIR OF C. F. P. VON MARTIUS.*

By Charles Rau.

The family of the celebrated botanist and ethnologist, to whose memory this sketch is dedicated, traces its origin back to Galeottus Martius, a famous physician and astrologer, born in 1427, at Narni, in Umbria. About the year 1450 he occupied a professorial chair at Padua, but, persecuted by the Inquisition on account of reformatory tendencies and compelled to leave Italy, he subsequently went to the court of the learned King Matthias Corvinus of Hungary, who appointed him his counsellor and librarian. The descendants of Galeottus mostly spread themselves over Germany, and many are known to have pursued learned professions, thus forming an ancestry worthy of their distinguished successor.

Carl Friedrich Philipp von Martius was born on the 17th of April 1794, at Erlangen, Bavaria, where his father, Ernst Wilhelm Martius, owned an apothecary establishment, holding at the same time the position of honorary professor of pharmacy in the university of that city. A man of superior general acquirements, he was especially interested in botany, and has left some writings relative to his favorite study. At the advanced age of ninety, he published an interesting and well-written book, containing recollections of his long and eventful life. He died in 1849, in his ninety-third year.

His eldest son, the subject of this sketch, was carefully educated at home and in the schools of Erlangen. At an early age he already displayed the germs of those talents which afterward made him conspicuous in the world of letters, and, when still quite young, he manifested a determined resolution to devote himself to a scientific career. Though his juvenile inclinations leaned toward natural history, he also exhibited much taste for the study of ancient classics, a tendency which, nurtured by skillful teachers, not only developed and strengthened his intellectual capacities, but also enabled him, when in after years he composed many of his writings in Latin, to express himself in that language with a precision and elegance not often met with in our time. In fact, during his whole life the reading of Latin and Greek authors formed one of his principal recreations. When only sixteen years of age, Martius was admitted, in 1810, as a student in the university of his native town. He had decided to prepare himself for the medical profession, chiefly because this study afforded him the widest field for indulging in his love for natural sciences. His favorite branch, botany, was then taught at Erlangen by a pupil of Linnæus, the learned Schreber, who does not seem, however, to have been gifted with a happy method of imparting information; hence Martius and his fellow-students felt more attracted by the lectures

* Note.—It is but fair to state that most of the facts contained in this sketch have been furnished by C. F. Meissner's *Denkschrift auf Carl Friedr. Phil. von Martius*, (Munich, 1869.) The article *Carl Philipp von Martius, sein Leben und seine Leistungen*, in the *Ausland*, (No. 38, 1869,) has also been used.

of other professors of the university, such as Hildebrandt, Harless, Goldfuss, Vogel, Wendt, and others who flourished at that period. In 1814 Martius received the diploma of *doctor medicinæ*, having passed with honors the examination necessary to obtain that grade. His inaugural dissertation was a critical catalogue of the plants in the botanical garden of Erlangen.* In this first literary attempt, which forms an octavo volume of 210 pages, he followed the classification of Linnæus. Shortly afterward we find Martius among the *élèves* of the Royal Academy of Sciences at Munich, deeply engaged in botanical studies, and appointed assistant to Schrank, the conservator of the botanical garden. An excellent opportunity being thus offered to the young botanist of enlarging the knowledge already acquired, he devoted himself with enthusiastic zeal to a pursuit that harmonized so well with his taste. While in this position he published his *Flora Cryptogamica Erlangensis*, (*Norimbergæ*, 1817,) a work already begun at Erlangen, which embraced his first independent investigations, and attracted by its merits considerable attention from competent botanists. His superior talents, combined with an indefatigable industry and excellent personal qualities, could not fail to endear him to the older members of the Academy, men eminent in their special departments of science, who exerted a most beneficial and lasting influence on his mind. Indeed, he was placed in an enviable position; fortune smiled on him and smoothed his path to distinction. One circumstance, however, must be particularly mentioned in this place; for it is that on which his future success in life chiefly depended. The King of Bavaria, Max Joseph I, an ardent lover of botany, frequently visited the botanical garden of his capital, on which occasions he usually selected Martius for his companion and guide. Thus becoming acquainted with the young naturalist's acquirements and talents, he honored him with his special favor, and seized upon the first opportunity of showing his good will in a practical manner. This excellent monarch had for some time conceived the plan of sending scientific explorers to South America, and in 1815 he had already conferred with the Academy in relation to this matter; yet two years elapsed before the realization of his design. In 1817, when the Austrian Archduchess Leopoldina, the bride of the crown-prince of Brazil, afterward Emperor Dom Pedro I, was about to depart for the New World, Metternich caused some Austrian savants, charged with scientific labors in Brazil, to be added to the suite of the princess. The Bavarian government, wishing to profit by this occasion, asked, and was granted, permission to send in the same vessel two naturalists, who, upon their arrival in South America, were to carry on their investigations independently of the Austrian corps. For this purpose Max Joseph selected as botanist his gifted protegé Martius, then a young man of twenty-three, and Johann Baptist von Spix, a member of the Academy, who was to take charge of the zoological department. On the 2d of April, 1817, the party left the harbor of Trieste in the Austrian frigate Austria, and touching at Malta, Gibraltar and Madeira, reached Rio Janeiro, after a prosperous voyage, in the middle of July. One may easily imagine the feelings of the two travelers, especially of the youthful and enthusiastic Martius, when they stood upon the soil of the wonderful country that lay before them with all its treasures of nature—the very El Dorado of a naturalist, then far less explored than at the present time, and promising the richest harvest in every field of natural science.

On the 8th of December, 1817, the two Bavarian savants set out on their expedition into the interior. Having first visited the province of

* *Plantarum Horti Academici Erlangensis Enumeratio. Erlangæ*, 1814.

San Paolo, they passed in a northeasterly direction through the province of Minas Geraës as far as Minas Novas; then through the Serra Diamantina, touching the province of Goyaz, when they turned again toward the northeast and proceeded to San Salvador, the capital of the province of Bahia. They arrived there in November 1818. After a short sojourn at this place, and having visited the Botocudos and other adjacent Indian tribes, they continued their journey toward the north, traversing the provinces of Pernambuco, Piauhy, and Maranhão, until they reached San Luiz, situated at the mouth of the Itapicurú. From there they went by sea to the estuary of the Amazon River, arriving at Para in June 1819. They then ascended this mighty stream for more than two-thirds of its length, as far as Tabatinga, close to the frontier of Peru. The travelers having separated for awhile to visit different parts of this region, Martius explored one of the tributaries of the Amazon, the Rio Japurá, (Yupurá) until he arrived at the cataract Salto Grande de Araracoara, which impeded a further advance. The larger affluents of the great river, the Rio Negro and Rio Madeira, were likewise explored some distance, the latter as far as the districts of the Mundrucú and Mauhé Indians. It must be remembered that the navigation of those waters, which is now greatly facilitated by steam vessels, had then to be performed in hired or purchased boats, which, being manned with Indian rowers, afforded hardly room for the travelers and their ever increasing luggage, and offered no other protection against the burning equatorial sun and the heavy rains but a slight cover constructed of boughs. Amid a multitude of inconveniences, and sometimes exposed to real danger, they had to keep their journals, and to prepare and preserve the natural objects obtained during their excursions on the banks; yet the collections they brought back, which now enrich the museums of Munich, bear evidence of their great success.* Descending the Amazon, they arrived again in Para in the middle of April 1820. Two months afterward they embarked for Lisbon, and reached Munich in December 1820, after an absence of nearly four years.

The expedition of Spix and Martius certainly ranks among the most important enterprises undertaken for scientific purposes in this century. Their explorations extended over a distance of nearly one thousand four hundred geographical miles, and have, like the travels of Alexander von Humboldt, furnished the material for numerous works embracing many departments of science; indeed, the period of nearly half a century, which has elapsed since the return of the naturalists, was not sufficient for fully developing, and giving to the scientific world, all results of their researches. Since La Condamine descended the Amazon, Spix and Martius were the first learned Europeans who visited those mighty waters; and though others had previously explored certain portions of Brazil, the country, on the whole, still remained comparatively unknown. Hence the importance of the Bavarian expedition. The names of Spix and Martius are intimately connected with the natural history and ethnology of the empire, and will be gratefully remembered in future times by all those who take a scientific interest in that country, or wish to inform themselves concerning its condition in the early part of our century.

* Besides valuable mineralogical and geological specimens, their collections embraced: mammals, 85 species; birds, 350; amphibia, 130; fishes, 116; insects, 2,700; arachnidae and crustaceans, each 50; plants, about 6,500. The latter, mostly represented by several specimens and carefully preserved, constitute now the most valuable portion of the royal herbarium at Munich. The botanical garden also received its share, partly in living plants, partly in such as were raised from the collected seeds. The whole was placed under the care of the Academy.

The Brazilian voyage laid the foundation of Martius' future success. On the very day of their return, he and Spix were decorated by the King with the civil order of Bavaria, and shortly afterward Martius was elected a member of the Royal Academy, and appointed second conservator of the botanical garden. At the age of twenty-six Martius already enjoyed a reputation which, in common life, is usually only acquired by men of riper years; for not many are favored with advantages such as were offered to him. His sojourn in a country perfectly new to him, and hence the necessity of acting independently, had made him self-reliant and practical, while the number of objects constantly claiming his attention had served to quicken his power of perception, and to develop all those qualities which, when combined, constitute the true naturalist. His experiences in the wilds of Brazil were to him a far better school than many years spent in constant closet-study.

His return from Brazil marked the beginning of a long-continued literary activity, resulting in highly important works, to which reference will be made hereafter. As an event of this period we have also to record his marriage with an accomplished lady of noble descent, a union which gave him a home and a family, and promoted in no small degree the happiness of his existence. The domestic circle was to him throughout life an asylum of peace and contentment, where he rested from his professional labors, enjoying the society of his family and of numerous friends who loved to gather under his hospitable roof. A great change occurred in Martius' position in the year 1826, when King Ludwig I, who had ascended the throne of Bavaria, transferred the university of Landshut to Munich, and appointed him professor of botany. Six years later, the first conservator of the botanical garden, Von Schrank, being then very old, retired from office, and Martius was installed in his place. He was eminently qualified for discharging the duties now incumbent on him. Perfectly acquainted with his science, he possessed the faculty of presenting it in an easy and attractive manner. He spoke with elegance and fluency, and sometimes, when carried away by the subject, his eloquence even partook of a poetical character. For practical demonstration the botanical garden, carefully superintended by Martius, and the herbarium, afforded ample means, to which must be added frequent botanical excursions undertaken in company with the students, with whom he entertained very amicable relations, gaining their affections no less by conscientious instruction than by the benevolent, paternal friendship he bestowed on them. Among the number of his pupils who became prominent, may be named Alexander Braun, Hugo von Mohl, Carl Schimper, O. Sendtner, C. H. Schultz-Bipontinus, and Spring.

In 1840 Martius was elected secretary of the physico-mathematical class of the Academy, an honorary office imposing much labor, which he performed until his death with care and punctuality, and great advantage to that scientific body. By this position he was charged with all correspondence and literary exchanges with other learned institutions, and whenever a foreign or resident member of the Academy died it was his duty to deliver an address commemorative of the life and merits of the deceased. These eulogies have been much admired for the excellent style in which they are composed, and the skill displayed in the general treatment. They are deemed fully equal to the celebrated *éloges* by Cuvier and Flourens.*

* The eulogies read by Martius are contained in an octavo volume of 619 pages, entitled *Akademische Denkreden von C. F. Ph. von Martius*, (*Leipzig*, 1866.) Those of a later date (on Faraday, Brewster, Flourens, &c.) were published in the transactions of the Academy of the year 1868.

For the rest, the professional career of Martius is not marked by any striking incidents. Lectures, literary labors, and the superintendence of the botanical garden fully occupied his time, and his travels, after the American voyage, extended not farther than France, Belgium, Holland, England, and Switzerland. He used to spend his summer vacations in the picturesque Bavarian mountains, especially at Schlehdorf, on the Kochel-See, where his hospitable house formed a rallying-place for his numerous friends, who remember with feelings of gratitude the days passed there amid delightful natural scenes and in a highly intellectual, refined society. Though of a vigorous constitution, Von Martius was in later years subject to those chronic indispositions which usually result from the sedentary habits of men of letters, and he found himself therefore obliged to resort repeatedly to watering places, especially to the mineral springs of Kissingen. The salutary effect derived from the use of these waters was in some measure counteracted by the bustle and distractions peculiar to such localities; for, meeting there distinguished friends, and being, moreover, naturally inclined to social life, the mental excitement produced was rather unfavorable to the improvement of his physical condition.

In the year 1854 an unexpected event caused the premature termination of Martius' official activity. It was decided by the government that the glass building for the industrial exhibition then to be held at Munich should be erected within the area of the botanical garden, which had but lately undergone great improvements at a sacrifice of much time and labor. It was in vain that Martius remonstrated against a measure which threatened his beloved institution with serious disadvantages, and when he found his objections unavailing, he finally resigned, deeply disappointed, both his professorship and the superintendence of the botanical garden.

The literary activity of Professor Von Martius was very great. The writer has in his possession a printed list of his works and minor writings, which embraces no less than one hundred and sixty titles. A number of these publications are written in the Latin language, and most of them, of course, relate to botany, his specialty in science; but there are also valuable contributions to ethnology among them. In treating of his merits as an author, it is proper to mention first the narrative of the Brazilian voyage performed by him and Spix.* This is a substantial and most carefully prepared work, in three quarto volumes, accompanied by an atlas of large size. The volumes appeared respectively in 1823, 1828, and 1831; Spix, however, died in 1826, and hence the two last volumes were almost entirely written by Martius alone. Every one who examines this work must be struck by the vast amount of varied information it contains, for the travelers directed their attention not merely to the natural history of Brazil, but investigated also with searching care everything else within their reach which they deemed worthy of inquiry. The nature of the country, its productions, different races, social condition, commerce, agriculture, mining, statistics, &c., are treated with a surprising minuteness, and, where the subject is of an elevated character, in a superior style, which has repeatedly

* *Reise in Brasilien, auf Befehl Sr. Majestät Maximilian Joseph I, Königs von Bayern, in den Jahren* 1817, 1818, 1819 *und* 1820 *gemacht, und beschrieben von J. B. von Spix und C. F. Ph. von Martius.* Three vols., 4to; Munich, 1823–31; with an atlas.
There is an English translation of the first volume by H. E. Lloyd; London, 1824; 2 vols., 8vo.; plates reduced to the size of the volumes.

elicited the praise of Goethe, the great master of German composition. In fact, certain portions of the work, such as give the impressions produced upon the travelers by the sublime natural scenes of Brazil, have passed into collections containing model pieces of German prose.* The large atlas, ornamented with a well-executed allegorical title-page, comprises maps, orographical diagrams, panoramic views of mountain chains, landscapes, representations of typical animals and plants, and quite a number of plates illustrating the domestic and hunting life, the feasts, dances, and ceremonies of the aboriginal inhabitants. Their fabrics and arms are figured on two plates. In addition, there are many faithfully executed, large portraits of Indians of various tribes, exhibiting their peculiar features and the curious manner in which they disfigure their ears, lips, and chins by the insertion of ornaments. Of particular interest are some plates containing representations of figures sculptured on rocks, as affording the means of comparing the pictography of the Brazilian aborigines with that of other indigenous inhabitants of the American continent.

On the whole, the narrative of Spix and Martius is one of the most important and comprehensive works of travel published in modern times, equaling in merit the researches of Humboldt relative to Mexico and other parts of America. It will remain a lasting monument of the zeal and perseverance of its authors, and an honorable testimonial to the enlightened prince who brought about its realization.

Simultaneously with the account of their travels, Spix and Martius began to prepare their strictly scientific works on the botany and zoology of Brazil; the former department, of course, being in charge of Martius, while Spix treated the subject of zoology. But as Spix had

* We cannot refrain from inserting here, as a specimen, the description of evenings spent at the country house of Mr. Von Langsdorff, near Rio Janeiro:

"Nothing can be compared to the beauty of this retreat when the most sultry hours of the day are past, and gentle breezes, impregnated with balsamic perfumes from the neighboring wooded mountains, cool the air. This enjoyment continues to increase as the night spreads over the land and the sea, which shines at a distance, and the city, where the noise of business has subsided, is gradually lighted. He who has not personally experienced the enchantment of tranquil moonlight nights in these happy latitudes can never be inspired, even by the most faithful description, with those feelings which scenes of such wondrous beauty excite in the mind of the beholder. A delicate, transparent mist hangs over the country, the moon shines brightly amidst heavy and singularly grouped clouds; the outlines of the objects which are illuminated by it are clear and well defined, while a magic twilight seems to remove from the eye those which are in the shade. Scarce a breath of air is stirring, and the neighboring mimosas, that have folded up their leaves to sleep, stand motionless beside the dark crowns of the manga, the jaca, and the ethereal jambos; or sometimes a sudden wind arises, and the juiceless leaves of the acaju rustle, the richly flowered grumijama and pitanga let drop a fragrant shower of snow-white blossoms; the crowns of the majestic palms wave slowly over the silent roof which they overshade, like a symbol of peace and tranquillity. Shrill cries of the cicada, the grasshopper, and the tree-frog make an incessant hum, and produce by their monotony, a pleasing melancholy. A stream, gently murmuring, descends from the mountains, and the macuc, (*Perdrix guyanensis*,) with its almost human voice, seems to call for help from a distance. Every quarter of an hour different balsamic odors fill the air, and other flowers alternately unfold their leaves to the night, and almost overpower the senses with their perfume; now it is the bowers of paullinias, or the neighboring orange grove, then the thick tufts of the eupatoria, or the bunches of the flowers of the palms, suddenly bursting, which disclose their blossoms, and thus maintain a constant succession of fragrance. While the silent vegetable world, illuminated by swarms of fire-flies, as by a thousand moving stars, charms the night by its delicious effluvia, brilliant lightnings play incessantly in the horizon and elevate the mind in joyful admiration to the stars, which, glowing in solemn silence in the firmament above the continent and ocean, fill the soul with a presentiment of still sublimer wonders. In the enjoyment of the peaceful and magic influence of such nights, the newly-arrived European remembers with tender longings his native home, till the luxuriant scenery of the tropics has become to him a second country."—(English translation, vol. i, p. 160.)

died in 1826, the assistance of Agassiz, Perty, and Andreas Wagner was required to continue the zoological labors, which resulted in the publication of several folios with beautifully executed plates. We mention the following:

New species of Brazilian monkeys and bats, by Spix.* New species of lizards, snakes, turtles, and frogs, by Spix.† New species of birds, by Spix.‡ Fluviatile testaceans, by J. A. Wagner.§ Fishes, by Agassiz.‖ Insects, by Perty.¶

In treating of the Brazilian flora,** Martius first confined himself to a selection of the plants collected by him, which he described in two works, entitled *Nova Genera et Species Plantarum Brasiliensium* †† and *Icones Selectæ Plantarum Cryptogamicarum Brasiliæ.* ‡‡ In the preparation of the first volume of the first-named work, which describes the phanerogamous plants, he was assisted by his too-early-deceased colleague Zuccarini. The object of the *Icones Selectæ, &c.*, is indicated in the title. To the latter work Hugo von Mohl contributed an excellent treatise on the structure of the stems of tree-ferns. Both works are highly esteemed. They contain full and precise descriptions of single plants as well as of whole series and groups of kindred species; and it is particularly worthy of notice that many of these monographic treatises have laid the foundation of a thorough knowledge of the plants to which they relate. The drawings of whole plants and their anatomical details are executed with a degree of faithfulness and art surpassing almost anything of a similar character that had previously appeared in the literature of botany.

As early as 1823 Martius began the publication of his "Natural History of Palms,"§§ a work which is considered his most important contribution to botany, and that by which he has most conspicuously linked his name for future times with that science. At the first sight of these majestic trees, which Linnæus already had designated as the "princes of the vegetable kingdom," he conceived the plan of making them the object of his special observation and scientific treatment. He, therefore, studied with attention the many species of palms he saw during his travels in Brazil, and collected after his return from that country with the utmost diligence all the material concerning the palms of other parts of the world, which was required to render his work complete. He thus succeeded, after the labor of many years, in producing a monograph unique in its kind, which caused Alexander von Humboldt to exclaim, "As long as palms are known and mentioned, the name of

* *Simiarum et Vespertilionum Brasiliensium Species Novæ. Ed. J. B. de Spix. Monachii,* 1823. Large folio, with 38 colored plates.

† *Animalia Nova, s. Species Novæ Lacertarum, Serpentum, Testudinum, Ranarum, quas in Itinere per Brasiliam a.* 1817–'20 *suscepto, collegit et descripsit J. B. de Spix. Monachii,* 1824–'39. Folio, with 95 colored plates.

‡ *Avium Species Novæ quas in Itinere per Brasiliam a.* 1817–'20 *suscepto collegit et descripsit J. B. de Spix. Monachii,* 1824–'25. Two volumes folio, with 115 and 118 colored plates.

§ *Testacea Fluviatilia quas* —— —— *collegit J. B. de Spix, descripsit J. A. Wagner, edd. F. a Paula de Schrank et C. F. P. de Martius. Monachii,* 1827. Folio, with 29 colored plates.

‖ *Selecta Genera et Species Piscium quos* —— —— *collegit et pingendos curavit J. B. de Spix, digessit L. Agassiz,* ed. *Martius. Monachii,* 1829. Folio, with plates.

¶ *Delectus Animalium Articulatorum quæ* —— —— *collegerunt Spix et Martius, descripsit Max. Perty, ed. Martius. Monachii,* 1830–'34. Folio, with 40 colored plates.

** Not being a botanist himself, and consequently unacquainted with most of the works mentioned hereafter, the writer keeps closely to the statements given by Professor Meissner in his *Denkschrift*.

†† *Monachii,* 1823–'30. Three volumes folio, with 300 colored plates.

‡‡ *Monachii,* 1826–'31. Small folio, with 76 colored plates.

§§ *Historia Naturalis Palmarum. Monachii,* 1823–'50. Three volumes imperial folio, with 245 plates, partly colored.

Martius will not be forgotten!" Certain specialties embraced in this large work were treated by skillful co-laborers: the anatomy, by H. von Mohl; the fossil palms, by Unger; and a part of the morphology by Alexander Braun and O. Sendtner.

While the preceding works were commenced and in progress, Martius entered upon another literary undertaking of still larger extent, namely, the systematic enumeration and description of the whole flora of Brazil. But as a labor of such magnitude could not be carried out without the assistance of persons in high stations, the patronage of King Ludwig I, of Bavaria, and of the Emperor of Austria, Ferdinand I, was successfully solicited, and the work commenced under their auspices.* The Emperor Dom Pedro II, of Brazil, afterward united his aid to that of the two German sovereigns. At the outset Martius had secured the co-operation of competent botanists, each of whom was to take charge of a certain portion of the work; and their united efforts resulted in the publication of the *Flora Brasiliensis*,† one of the greatest literary achievements of our time. The work was commenced in 1840, and though yet far from completion, already consists of forty-seven parts, with more than *eleven hundred* plates in folio. Notwithstanding the ample material which Martius had at his command, the researches necessary to arrive at full and satisfactory results extended over many botanical collections of Europe, and everything in the shape of manuscripts and drawings bearing on the subject was critically examined and used when found available. The immense work connected with the editing of the *Flora* prevented Martius from participating conspicuously in the botanical labors themselves; yet he has furnished two entire monographs (Anonaceæ and Agaveæ) and many highly valuable additions relating to the geographical distribution and the use of the plants described. In view of the important bearing of this publication upon the development of the vegetable resources of Brazil, the ambassador from that country to the court of Vienna lately spent some time at Munich, in order to confer with Professor Von Martius concerning the completion of the work. The Brazilian government agreed to pay 100,000 florins for that purpose; but as Martius was already far advanced in years, he thought it expedient to appoint, in the person of Dr. Eichler, a successor to superintend the publication in case of his decease. Thus the work will suffer no interruption.‡

* It must not be left unnoticed that the patronage of the Emperor of Austria in this case was owing to the influence of Prince Metternich. This much-abused statesman, it is well known, took a lively interest in the promotion of science. His letters to A. von Humboldt, contained in the correspondence between Humboldt and Varnhagen von Ense, bear witness to the fact.

† *Flora Brasiliensis, s. Enumeratio Plantarum in Brasilia hactenus detectarum quas — — ediderunt C. F. Ph. de Martius et St. L. Endlicher. Vindob. et Lips.*, 1840–'69, *fasc.* 1–47, *folio* . The first nine parts were edited by Martius and Endlicher; the rest, after Endlicher's death, by Martius alone.

‡ Of Martius' numerous less extensive publications relating to botany we will mention only the following:

Herbarium Floræ Brasiliensis. Monachii, 1837–40.—*Systema Materiæ Medicæ Vegetabilis Brasiliensis.* (8^{c}: Leipzig, 1843.) This is a systematically arranged enumeration of the plants used for medicinal purposes by the inhabitants of Brazil. The preparation, manner of application, and effects are carefully described. This work has been translated into the Portuguese language by H. Velloso d'Oliveira. Rio de Janeiro, 1854.

Specimen Materiæ Medicæ Brasiliensis (in vol. ix, of the Memoirs of the Academy of Sciences.) A number of articles likewise relating to the medicinal plants of Brazil and their uses were published in *Buchner's Repertorium der Pharmacie.*

Worthy of especial mention is a publication on the potato-rot: *Die Kartoffel-Epidemie der letzten Jahre* (Munich, 1843. 4°. With plates.) Martius was the first who noticed in the diseased fruit a microscopic fungus, called by him *Fusisporium solani.* He accounted for the spreading of the rot by the transmission of the spores of that fungus to sound potatoes.

Having given some account of Martius' more important botanical labors, we will briefly allude to his great merits as an ethnologist. During his travels in South America he became deeply interested in the aboriginal tribes, and collected, in conjunction with his traveling companion, many valuable facts relating to their mode of life, relationship, languages, migrations, &c. It has already been stated that a considerable portion of the "Travels in Brazil," by Spix and Martius, is devoted to the ethnology of that country. Martius, however, published subsequently several valuable treatises relating to ethnological subjects, which will be mentioned hereafter; but his most important ethnological work, entitled *Beiträge zur Ethnographie und Sprachenkunde Amerikas, zumal Brasiliens*, (Leipzig, 1867,)* which was published shortly before his death, and therefore contains his matured views, deserves particular notice. The *Beiträge* comprise two octavo volumes, the first of 802, the second of 548 pages. An ethnographic map is added to the first volume. Its contents are:

1. *Die Vergangenheit und Zukunft der amerikanischen Menschheit*,† a lecture delivered in 1838, at a meeting of German naturalists and physicians, and first published in 1839.

2. A republication of the admirable treatise *Von dem Rechtszustande unter den Ureinwohnern Brasiliens*,‡ first published in 1832. This is certainly one of the most interesting essays ever written on American ethnology, although Martius' view of a degeneration of the Brazilian Indians from a higher state of civilization may be contrary to the opinions of many anthropologists.

3. The remainder of the volume (pp. 145–801) is taken up with a description of the native tribes who inhabit Brazil and the adjacent regions. It is minute, accurate, and vivid, much more full than Waitz, and enriched by numerous personal observations. Martius is a believer in the gradual extension of the Tupi language and blood from the head-waters of the La Plata northward, quite to the Antilles and Bahamas.§

The second volume, entirely devoted to South American languages, contains over a hundred vocabularies, which are arranged in allied groups exhibiting the affinity of tongues. Being of the utmost importance in tracing the relationship of nations, they furnish highly valuable material to the student of American ethnology. Many of these vocabularies are from manuscript sources. In rendering the aboriginal words the Latin, Portuguese, German, and French languages have been employed. The articles *Pflanzennamen in der Tupi-Sprache*‖ and *Thiernamen in der Tupi-Sprache*,¶ first printed, respectively, in 1858 and 1860, are republished with additions in this volume.

Besides the above-mentioned ethnological essays reprinted in the *Beiträge*, Martius, as stated, has left some other contributions of kindred character, which appeared in periodical publications. We give here the following titles translated into English: On the sculptures on Mount Gabia," near Rio Janeiro.** On Buschmann's work—"The traces of the

* Contributions to the ethnography and philology of America, especially of Brazil.

† The past and future of the American race.

‡ On the civil and social condition of the aborigines of Brazil.

§ In a letter which Martius addressed, shortly before his death, to Dr. D. G. Brinton, of Philadelphia, he expresses himself on this point even more decidedly than in the *Beiträge*.

‖ Names of plants in the Tupi language.

¶ Names of animals in the Tupi language.

** *Ueber die Sculpturen auf dem Berge Gabia bei Rio de Janeiro.* (*Gelehrte Anzeigen*, 1843, Nos. 38, 39.)

Aztec language in Northern Mexico."* The physical condition, diseases, physicians, and remedies of the aborigines of Brazil.† On the preparation of the arrow-poison Urari among the Juri Indians on the Rio Yupurá, in North Brazil.‡ The creation of the Negro: a Brazilian legend.§

The time intervening between Professor Von Martius' retirement from official duties in 1854 and his death was to him no period of repose; ‖ on the contrary, having now more leisure at his command, he devoted himself exclusively to scientific labors. Much of his time was taken up in editing the *Flora Brasiliensis*, and his position as secretary of the Royal Bavarian Academy demanded his constant care and attention. Only one year before his death, at the age of seventy-four, he published the *Beiträge*, his most important contribution to American ethnology.

He was one of those few whose merits are duly acknowledged and appreciated during their life-time. He maintained intimate relations with many of the most distinguished men of our time, and most learned societies of note counted him among their members. Numerous works are dedicated to him; his name is perpetuated in the scientific denominations of plants and animals; even a mountain in New Zealand, Mount Martius, is called after him. Medals were struck in his honor, and crowned heads manifested their esteem by decorating him with the insignia of their orders.

Martius enjoyed the full possession of his mental faculties to the last moment of his life, and even his physical appearance betokened no considerable degree of decline; it was only during the years immediately preceding his death that his altered features and somewhat stooping figure indicated the changes which advanced age will produce upon the strongest constitution. But the lively expression of his eye, his animated conversation, and the interest he took in everything that passed around him, gave evidence of his unimpaired mental vigor. In the fall of 1868, being then in his seventy-fifth year, he made a journey to Berlin and Dresden to visit his son and his old friends. He returned in good health, and nothing intimated his approaching end. But shortly afterward, having been exposed to a severe storm, he was attacked by a febrile indisposition, which, increasing, developed itself into inflammation of the lungs. His strength sank rapidly, and on the 13th of December, 1868, after an illness of nine days, his earthly career was closed by an easy death. Fresh palm leaves decorated, significantly, the coffin in which his mortal remains were conveyed to their last place of rest.

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* *Ueber Buschmann's Werk: Die Spuren der Aztekischen Sprache im nördlichen Mexiko.* (*Gel. An.*, 1860, *Nos.* 41–43.)

† *Das Naturell, die Krankheiten, das Arztthum und die Heilmittel der Urbewohner Brasiliens.* (*Büchner's Repertorium der Pharmacie*, vol. 33, p. 289, &c.)

‡ *Ueber die Bereitung des Pfeilgiftes Urari bei den Indianern Juris am Rio Yupurá in Nordbrasilien.* (*Buchner's Rep. d. Pharm.*, vol. 36, 1830, p. 337, &c.)

§ *Die Erschaffung des Negers, eine Brasilianische Volks-Sage.* (*Augsburger Allgem. Zeit.*, 1839.)

‖ "*Der Ruhestand war für ihn kein Stand der Ruhe.*"—Meissner's *Denkschrift*, p. 24.

NOTICE OF THE LIFE AND SCIENTIFIC LABORS OF STEFANO MARIANINI.

By Carlo Matteucci,
President of the "Italian Society of Sciences, founded by Anton Mario Lorgna."

[*Translated for the Smithsonian Institution.*]

It is not such a eulogy as is usually pronounced for the members whom the Italian Society of the XL may have lost that I at present undertake. This several reasons forbid, not the least of which is my own unskillfulness in the polished style of composition which such labors demand, joined to a conviction that the highest eulogy of those who have consecrated their lives to science consists in the record of the progress which it owes to their exertions, and the part reserved for them in its history. I shall speak, therefore, with the utmost brevity of the simple habits, the pure and unassuming spirit, the integrity of character, and the great scientific activity of Marianini, although these qualities constitute in themselves the best eulogy of the man, and shall dwell at somewhat greater length on his principal labors in physics.

Marianini was born at Mortara, a small town of Piedmont. He was professor of physics at Venice, and more recently in the University of Modena; he was a corresponding member of the Institute of France, and president of the Italian Society of the XL for many years.

The first work by which he attracted the attention of the learned was an *Essay on electro-metrical experiments*,* a work which I remember to have heard spoken of, at the time, in terms of the highest praise by Arago. It appeared at Venice in 1825. On account of the original experiments with which it is replete we need not hesitate to pronounce it the most important production of the author. When it is considered that in various chapters of this essay all parts of electro-dynamics and of the pile are treated by methods and with instruments which were then barely beginning to be known, we need not be surprised if the results at which Marianini arrived at that time have not remained in science as he himself obtained them forty years ago. If we except the discoveries of elementary laws and of physico-mathematical theories, this is the lot which befalls, after a certain number of years, even those who have opened new fields in physics.

Marianini, in this essay, began by studying the relation between the intensity of the current of a battery and the extension of the elements and tension of the electro-motors: that is to say, the number and nature of the pairs which compose the pile. He then proceeded to experiment on the relative electro motive power of conductors of the first class, and studied the phenomenon of the secondary current, respecting which he has left us some valuable experiments. In the third chapter of the essay are comprised many original researches on the conductive capacity of liquids for electricity. It is beyond doubt that this treatise marks a great progress in our knowledge on the most obscure and difficult points

* *Saggio di esperienze elettro-metricha.*

of dynamic electricity; and the discovery then made by Marianini, which may in some measure be considered as the experimental basis of the theory of Ohm, is still a fundamental one, namely, that the action of simple electro-motive machines on magnets, to use his own words, is directly proportional to their surface, and that in a circuit having a resistance *quasi* null in comparison with that of the battery, the current of a pile of a single pair has the same intensity with that of any number of pairs whatever.

In the same chapter the author studies the phenomenon of metallic diaphragms interposed in a liquid stratum to the passage of the current. The catalogue which is given in the essay of conductors of the first class, according to the decreasing order of their relative electro-motive power, is established with much exactness, and may even now be said closely to approximate the truth.

In speaking of the conductibility of liquids, a subject in regard to which the physicists of our own day well know the difficulty of arriving at exact measurements, Marianini proves for the first time, what has never since been contradicted, that the conductibility of liquids increases with the temperature; that this augmentation is less in liquids endowed with a great conductibility, and that a heated liquid preserves for a certain time in growing cold a greater conductibility than it first had at a given temperature. Here he finds by experiment that the resistance of a liquid stratum increases with the thickness of the stratum, and shows by many researches the augmentation of the effects of a battery by increasing the size of the plate of copper which incloses the zinc. There are also contained in the chapter on the conductibility of liquids some experiments, among which I will cite, as worthy of being varied and extended, that of the conductibility communicated by certain salts and organic compounds to a liquid such as alcohol, which is itself scarcely a conductor.

In 1826 Marianini read before the Atheneum of Venice a memoir on Ritter's battery, and on secondary polarity, in which by many well-devised experiments he more conclusively proved, what had been asserted by Volta, that the polarities of secondary batteries depended on the alterations which the current of the pile produces in the surface of the metallic disks of Ritter's column. In fact, after these disks have been washed and wiped dry, the column remains as active as before.

More recently Marianini undertook the study of electro-physiological phenomena, and in the memoir presented to the Academy of Roveredo in 1827, and which was translated in the *Annales de physique et de chimie*, t. XL, p. 225, the experiments are described on which is founded the law, still known in Germany as *the law of Marianini*, that the electric current in traversing the nerves in the direction of their ramification, or the *direct* current, as Nobili called it, excites a contraction when it enters and a sensation when it ceases to pass; and that, on the contrary, when the current is inverse or traverses the nerves in the direction contrary to their ramification, a contraction is produced at the instant at which it ceases to pass, and a sensation at that when it begins to traverse the nerves. In this memoir, Marianini distinguishes the contractions produced by electricity into *idiopathic* contractions, which are excited whatever be the direction in which the current traverses the muscles, and *sympathetic* contractions depending on the direction in which the current traverses the motor nerves. In a second memoir, in which he treats specially of the voltaic alternations, he shows that these depend on the diminution of excitability of the nerves, produced by the passage of the current in a certain direction. Among these experiments,

we must not fail to recall that by which Marianini obtains the shock at the opening of the circuit, although in the act of closing the circuit by means of the finger or other unmoistened body, this shock be not obtained. He subsequently occupied himself with the application of his studies on electro-physiology to the cure of certain cases of paralysis, and is, perhaps, the only physicist who has studied this subject with suitable attention, and obtained by electricity the restoration in some cases of those afflicted with this disorder.

Among the numerous memoirs of Marianini, we must also cite as worthy of remembrance and full of ingenious experiments, those with which he sought to sustain the theory of the electro-motive force of Volta and to combat the chemical theory of the pile. Although it be scarcely necessary to say that at present the latter theory is with reason generally embraced, there are, nevertheless, some experiments of Marianini which show that there are certain cases in which distinct signs present themselves of the electro-motive force as understood by Volta, without the appearance of any phenomena of chemical action to which those signs might be attributed.

It remains, finally, to cite a long series of memoirs in which our colleague studied the magnetizing force of the electric discharge of the Leyden jar, as well as the inductive discharges. For the prosecution of these experiments, Marianini commenced by inventing a *re-electrometer*, as he called it, which even now might be of service in many researches, and which consists of an iron wire surrounded by one of copper winding spirally about it, and placed above a compass in a direction perpendicular to the magnetized needle. A discharge from the jar, however weak, now passes by the spiral and magnetizes the iron wire, and the needle of the compass is deflected; the direction of the deviation indicating the direction of the discharge. In this memoir a great number of experiments are described, by which it is proved that, after the magnetization generated by an instantaneous discharge, if the magnetization be annulled either by mechanical means or by contrary discharges, the iron acquires a susceptibility of being magnetized in the first direction, and loses the susceptibility of being magnetized in the opposite direction. The author has studied with much sagacity all the other conditions of this phenomenon, namely, the thickness of the iron wires, the capacity of the Leyden jar from which the discharge is obtained, and compares the effects of a bundle of fine iron wires with those of a large and full cylindrical wire.

In continuation of these studies, Marianini proceeded to experiment on the effects produced by metallic envelopes in diminishing the magnetizing action of electric currents on the iron placed in the interior of those envelopes, and demonstrated that the effects depend on the action of the inductive discharge developed in the envelopes. He proceeded afterwards to the study of inductive discharges; discovered the inductions of the second and third order, which had been found at the same time by Henry, in America, and saw that the Leyden-electric induction was exerted also between liquid conductors.

These notices, by which we have certainly had no thought of rendering justice to the various labors of Marianini, will serve at least to show how assiduous and productive was the scientific life of our lamented colleague, and how admirable an example that life, prolonged as it fortunately was, offers, in its unobtrusive and tranquil course, to the youth of Italy—how imperishable an honor it will always reflect upon our country.

FLORENCE, *April* 1, 1867.

ON THE CHEMISTRY OF THE EARTH.

By T. Sterry Hunt, LL. D., F. R. S.

In the following pages I have endeavored, at the request of Professor Henry, to give a brief summary of certain views in chemical geology which have been put forward by me in various scientific journals during the past twelve years, the germ of them having appeared in a communication to the *American Journal of Science* in January, 1858. In addition to the foot-notes, I have appended a list of my principal publications on the subject, where those who desire to follow up the various questions here suggested will find them treated more at length. The last three of these papers are in part reprinted in the present abstract. I take this occasion to say that the views here embodied will be developed in a work on the chemistry of the globe, the preparation of which is now well advanced.

T. STERRY HUNT.

Montreal, *January* 6, 1870.

List of the principal papers, by Mr. T. Sterry Hunt, relating to Chemical Geology.

On the Chemistry of the Primeval Earth. American Journal of Science, January, 1858.

On the part which the Silicates of the Alkalies may play in the Metamorphism of Rocks. Proc. Royal Society of London, May 7, 1857, and American Journal of Science, March, 1858.

On the origin of Feldspars, and on some points of Chemical Lithology. American Journal of Science, May, 1858.

On the Theory of Igneous Rocks and Volcanoes. Canadian Journal of Toronto, March, 1858.

On some points in Chemical Geology. Quarterly Journal of the Geological Society, November, 1859.

Review of the last-named paper. American Journal of Science, July, 1860.

On Gypsums and Magnesian Rocks. American Journal of Science, September, November, 1859.

On the History of Lime and Magnesia Salts. American Journal of Science, July, 1866.

Contributions to Lithology. American Journal of Science, March, May, July, 1864.

Chemistry of Natural Waters. American Journal of Science, March, July, September, 1865.

Chemistry and Mineralogy of Metamorphic Rocks. Dublin Quarterly Journal, July, 1863.

Origin of some Magnesian and Aluminous Rocks. American Journal of Science, September, 1861.

La Chimie de la Terre. Comptes-Rendus de l'Académie, June 9, 1862.

The Earth's Climate in Paleozoic Times. American Journal of Science, 1863.

On some points in American Geology. American Journal of Science, May, 1861.

On the Chemical Geology of Mr. David Forbes. Geological Magazine, February, 1868.

On the Chemical Geology of Mr. David Forbes. Chemical News, February, 1868.

The Chemistry of the Primeval Earth. Lecture before the Royal Institution, May, 1867.

Volcanoes and Earthquakes. Lecture before the American Geographical Society, April, 1869.

On the Probable Seat of Volcanic Action. Geological Magazine, June, 1869.

CONTENTS OF SECTIONS.

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§ 1. In approaching the study of the chemistry of the earth, or what may be designated chemical geology, it becomes necessary to define the natural objects of that complex study to which is given the general name of geology, and also to consider its connection with the various sciences. To this end, some notions as to the order and the relation of these sciences may not be out of place. Following the classification established by Comte, we distinguish between the abstract sciences, which deal with laws, and the concrete sciences, which have to do with things. In their order the abstract sciences form an ascending series, according to the degree of complexity of their phenomena, "so that each science depends on the truths of all those which precede it, with the addition of peculiar truths of its own."—(J. S. Mill.) At the base of this series are thus placed—1st, *Mathematics*, with its successive divisions of number, geometry and mechanics; 2d, *Abstract Astronomy*, which considers, in addition to these, gravitation, taking cognizance of number, extension, equilibrium, and motion; 3d, *Physics*, comprehending the laws of weight, cohesion, sound, light, electricity, and magnetism; 4th, *Chemistry*, which treats of the relations to one another of the different forms of mineral matter, and their transformations under the physical agencies of light, heat, and electricity; 5th, *Biology*, or *Physiology*, to which belongs the study of the laws of organized growth and development; 6th, *Psychology*, which considers the laws of mental phenomena; and, 7th, *Sociology*, or the laws of human society.

§ 2. Parallel with these abstract sciences is a series of concrete or historical sciences, dealing not with laws and general principles, but with objects and facts. Of these concrete sciences the first is *Descriptive Astronomy*, which is the natural history of the planetary and stellar worlds, treating of their movements, dimensions, and cosmical relations. Coming, in the next place, to the history of our own planet, the study of the accidents of its surface and its interior gives rise to *Physical Geography* and to *Structural* and *Dynamical Geognosy;* while the bodies which it presents to us are naturally divided into two great classes, the inorganic or mineral kingdom, and the organic, including the vegetable and animal kingdom. The study of these two classes gives rise to two great branches of natural history, *Mineralogy* and *Organography*, the latter including *Botany* and *Zoology*. The concrete science of mineralogy has for its subject the natural history of all the forms of unorganized mat-

ter; that is to say, those substances which are exempt from biological laws, but come within the domain of physics and chemistry. Chemical change implies disorganization, and all so-called chemical species are inorganic, that is to say, unorganized, and belong to the mineral kingdom, whose natural history is thus physical and chemical, while that of the vegetable and animal kingdoms is biological.*

§ 3. It might, at first sight, seem foreign to our present subject to speak in this connection of the moral, social, and political history of mankind, dependent upon the laws of psychology and sociology. It is, however, to be remarked, that while in the abstract order each science is independent of that which follows it in the series, it is far different in the concrete sciences. This is seen in the familiar example of the dependence upon each other of the animal, vegetable, and mineral kingdoms, and it is evident that man puts in movement agencies which are constantly at work modifying alike physical geography and the relations of the mineral, vegetable, and animal world to such an extent that human history must not be disregarded in the study of the lower reigns of nature.

§ 4. From what has gone before it will be evident that under the common term of geology are generally confounded two distinct branches of study; the first or abstract division being that of the physical, chemical, and biological laws which have presided over the development of the globe, and the second or concrete division, the natural history of the earth as displayed in its physical structure, stratigraphy, mineralogy, paleontology. The name of geognosy, employed by some authors, may very appropriately be retained for the latter, while that of geology is restricted to the former division. It is proposed in the following pages to consider briefly some of the more important points in the chemical history of the globe; in doing which it will be necessary to notice also its astronomical and physical history, and the relations of organic life, in so far as they are concerned in the chemical history of the earth in its various stages of development. The scheme thus embraced is so great that in the limits of the present essay nothing more can be attempted than a sketch which shall embrace some of the most striking facts in the history of the forming globe considered as a condensing nebulous mass, in the chemistry of the air, sea, and earth in past ages, and in the relations of the central heat to the superficial portions of the earth, by which we shall endeavor to explain certain facts in dynamical geology, such as the great movements of the earth's crust and the phenomena of earthquakes and volcanoes.

§ 5. The nebular hypothesis, as it is called, which supposes that our solar system and all the worlds of space have come from the condensation of diffused vapors, has received strong confirmation from the discoveries made by the spectroscope. We now know that there exist in the heavens nebulæ consisting of luminous gas; that is to say, vaporous matter shining by its own light, which we may, with great probability, regard as the primal matter out of which, as the elder Herschel suggested, suns and planets have been formed by a process of condensation. By the aid of the telescope and the spectroscope we find in the heavens, planets—bodies like our earth, shining only by reflected light; suns,—self-luminous, radiating light from solid matter; and, moreover, true nebulæ, or masses of luminous vapor. These three forms represent three distinct phases in the condensation of the primeval matter, from which our own and other planetary systems have been formed.

* T. S. Hunt, on the Objects and Method of Mineralogy. American Journal of Science, [2,] xliii; 203.

This nebulous matter is conceived to be so intensely heated as to be in the state of true gas or vapor, and, for this reason, feebly luminous when compared with the sun. It would here be out of place to discuss the detailed results of spectroscopic investigation, or the beautiful and ingenious methods by which modern science has shown the existence in the sun, and in many other luminous bodies in space, of the same chemical elements that are met with in our earth.

§ 6. Calculations based on the amount of light and heat radiated from the sun show that the temperature which reigns at its surface is so great that we can hardly form an adequate idea of it. Of the chemical relations of such intensely heated matter modern chemistry has made known to us some curious facts, which help to throw light on the constitution and luminosity of the sun. Heat, under ordinary conditions, is favorable to chemical combination, but a higher temperature reverses all affinities. Thus, the so-called noble metals, gold, silver, mercury, &c., unite with oxygen and other elements; but these compounds are decomposed by heat, and the pure metals are regenerated. A similar reaction was many years since shown by Mr. Grove with regard to water, whose elements—oxygen and hydrogen—when mingled and kindled by flame, or by the electric spark, unite to form water, which, however, at a much higher temperature, is again resolved into its component gases. Hence, if we had these two gases existing in admixture at a very high temperature, cold would actually effect their combination precisely as heat would do if the mixed gases were at the ordinary temperature, and literally it would be found that "frost performs the effect of fire." The recent researches of Henry Sainte-Claire Deville and others go far to show that this breaking-up of compounds, or dissociation of elements by intense heat is a principle of universal application; so that we may suppose that all the elements which make up the sun or our planet would, when so intensely heated as to be in that gaseous condition which all matter is capable of assuming, remain uncombined, that is to say, would exist together in the condition of what we call chemical elements, whose further dissociation in stellar or nebulous masses may even give us evidence of matter still more elemental than that revealed by the experiments of the laboratory, where we can only conjecture the compound nature of many of the so-called elementary substances.

§ 7. The sun, then, is to be conceived of as an immense mass of intensely heated gaseous and dissociated matter, so condensed, however, that notwithstanding its excessive temperature, it has a specific gravity not much below that of water; probably offering a condition analogous to that which Cagniard de la Tour observed for volatile bodies when submitted to great pressure at temperatures much above their boiling point. The radiation of heat going on from the surface of such an intensely heated mass of uncombined gases will produce a superficial cooling, which will permit the combination of certain elements, and the production of solid or liquid particles; these, suspended in the still dissociated vapors, become intensely luminous, and form the solar photosphere. The condensed particles, carried down into the intensely heated mass, again meet with a heat of dissociation, so that the process of combination at the surface is incessantly renewed, while the heat of the sun may be supposed to be maintained by the slow condensation of its mass; a diminution by $\frac{1}{1000}$th of its present diameter being sufficient, according to Helmholtz, to maintain the present supply of heat for twenty-one thousand years.

§ 8. This hypothesis of the nature of the sun and of the luminous process going on at its surface is the one lately put forward by Faye,

and, although it has met with opposition, appears to be that which accords best with our present knowledge of the chemical and physical conditions of matter, such as we must suppose it to exist in the condensing gaseous mass which, according to the nebular hypothesis, should form the center of our solar system. Taking this, as we have already done, for granted, it matters little whether we imagine the different planets to have been successively detached as rings during the rotation of the primal mass, as is generally conceived, or whether we admit with Chacornac a process of aggregation or concretion operating within the primal nebular mass, resulting in the production of sun and planets. In either case we come to the conclusion that our earth must at one time have been in an intensely heated gaseous condition such as the sun now presents, self-luminous, and with a process of condensation going on at first at the surface only, until by cooling it must have reached the point where the gaseous center was exchanged for one of combined and liquefied matter.

§ 9. Here commences the chemistry of the earth, to the discussion of which the foregoing considerations have been only preliminary. So long as the gaseous condition of the earth lasted, we may suppose the whole mass to have been homogeneous; but when the temperature became so reduced that the existence of chemical compounds at the center became possible, those which were most stable at the elevated temperature then prevailing, would be first formed. Thus, for example, while compounds of oxygen with mercury, or even with hydrogen, could not exist, oxides of silicon, aluminium, calcium, magnesium, and iron might be formed and condensed in a liquid form at the center of the globe. By progressive cooling, still other elements would be removed from the gaseous mass, which would form the atmosphere of the non-gaseous nucleus. We may suppose an arrangement of the condensed matters at the center according to their respective specific gravities, and thus the fact that the density of the earth as a whole is about twice the mean density of the matters which form its solid surface may be explained. Metallic or metalloidal compounds of elements, grouped differently from any compounds known to us, and far more dense, may exist in the center of the earth. The condensing effect of pressure as we approach the center of the globe has, however, been regarded by some as far more than sufficient to account for the considerable mean density of the planet, and, according to Dr. Young, would be sufficient to reduce a mass of granite, transported to the earth's center, to one-eighth of the bulk which it occupied at the surface, which would give to the earth a mean density equal to twelve or thirteen times that of water. This consideration has led a recent writer to conclude, with Herbert Spencer, that our earth and the other planets may be only shells of varying thickness, inclosing a central cavity filled with vaporous matter, by which hypothesis may be explained their apparently feeble density. It is, however, a matter of indifference, so far as our argument is concerned, whether the process of condensation commenced around such a central cavity, or at the center of the globe itself.

§ 10. The processes of combination and cooling having gone on until those elements which are not volatile in the heat of our ordinary furnaces were condensed into a liquid form, we may here inquire what would be the result, upon the mass, of a further reduction of temperature. It is generally assumed that in the cooling of a liquid globe of mineral matter, congelation would commence at the surface, as in the case of water; but water offers an exception to most other liquids, in-

asmuch as it is denser in the liquid than in the solid form. Hence, ice floats on water, and freezing water becomes covered with a layer of ice, which protects the liquid below. Some metals and alloys resemble water in this respect. With regard to most other substances, and notably the various minerals and earthy compounds like those which may be supposed to have made up the mass of the molten globe, the case is entirely different. The numerous and detailed experiments of Charles Deville, and those of Delesse, besides the earlier ones of Bischof, unite in showing that the density of fused rocks is much less than that of the crystalline products resulting from their slow cooling, these being, according to Deville, from one-seventh to one-sixteenth heavier than the fused mass, so that if formed at its surface they would, in obedience to the laws of gravity, tend to sink as soon as formed.

§ 11. The stony materials of the earth's crust then, unlike ice and certain metals, expand in melting and contract in passing into the solid state. The melting of ice is a process of condensation, and hence pressure favors its liquefaction, causing it to melt at a lower temperature than it would otherwise do; but for bodies with which melting is a process of expansion, pressure produces an opposite effect, namely, that of augmenting the fusing point. These conclusions of James Thompson and William Thompson have been experimentally verified by Bunsen, Fairbairn, and Hopkins. It results from this physical law that the effect of pressure upon materials like molten rocks would be such that solidification at a depth from the surface would take place at a temperature much higher than that required for their solidification at the surface. Hence, in opposition to the notion of a congealed layer, like a sheet of ice, resting upon the surface of a molten globe, Hopkins, and with him Scrope, supposes solidification to have commenced at the center of the liquid mass and to have advanced toward the circumference. Mr. Hopkins concludes that the pressure existing at great depths must have induced congelation of the molten mass at temperatures at which, under a less pressure, it would have remained liquid. Before the last portions became solidified, there was produced, it is conceived by Mr. Hopkins, a condition of imperfect liquidity, preventing the sinking of the cooled and heavier particles, and giving rise to a superficial crust, from which solidification would proceed downward. There would thus be inclosed between the inner and outer solid parts, a portion of uncongealed matter, which, according to him, may be supposed still to retain its liquid condition, and to be the seat of volcanic action, whether existing in isolated reservoirs or subterranean lakes, or whether, as suggested by Scrope, forming a continuous sheet surrounding the solid nucleus.

§ 12. This view of the constitution of the globe, or one analogous to it, has found favor with many theorists. Professor N. S. Shaler, of Harvard, who, in a recent essay on the formation of mountain chains, in the proceedings of the Boston Society of Natural History, has adopted it, concisely states it as follows: "The earth consists of an immense solid nucleus, a hardened outer crust, and an intermediate region of comparatively slight depth, in an imperfect state of igneous fusion." In this connection it is curious to remark that, as lately pointed out by Mr. J. Clifton Ward, Halley was led, from the study of terrestrial magnetism, to a similar hypothesis. He supposed the existence of two magnetic poles situated in the earth's outer crust, and two others in an interior mass, separated from the solid envelope by a fluid medium, and revolving, by a very small degree, slower than the

outer crust.* The same conclusion was subsequently adopted by Hansteen.

§ 13. Apart from these considerations, however, many of the best modern physicists and geologists have found numerous reasons for rejecting the popular notion which regards our globe as a liquid molten mass covered by a layer of twenty or thirty miles of solidified rock. The deductions of Hopkins from the phenomena of precession and nutation, those of Pratt from the crushing force of immense mountain masses like those of the Himalaya, and those of Sir William Thompson from the tides, showing the great rigidity of the earth, all unite to prove that the earth, if not solid to the center, must have a firm and solid crust several hundred miles in thickness. Under these conditions, if there still exist a liquid center, it must, so far as superficial phenomena are concerned, be as inert as if it were not. We are thus prepared to accept the conclusions to which the line of argument in § 11 leads us, and admit that our globe solidified from the center.

§ 14. It is, then, with the superficial portions of the earth, alone, that we have to do from the moment of its solidification; and as in the subsequent pages of our history air and water must play an important part, it becomes necessary, before going further, to consider briefly the nature of the process of aqueous solution and its relations to pressure. Solution may, for our present purpose, be defined as a chemical union between two or more bodies, of which one is liquid, resulting in a liquid product, and accompanied by a change of volume.† In ordinary cases, as in that of most bodies dissolving in water, this change is in the direction of condensation, and hence, as might be expected, pressure exerts an influence similar to that in the liquefaction of certain bodies by fusion, explained in § 11. Pressure facilitates the liquefaction of ice, which is attended by condensation, and acts in like manner in the case of solution, so that the solubility of salts in water, as shown by the experiments of Sorby, is increased by pressure. We can scarcely doubt that these phenomena of fusion and solution come under one general physical law, and that for all those bodies which contract in dissolving, (to which there are but few exceptions,) their solubility in water must be augmented by and in proportion to the pressure. As expressed by Mr. Sorby, mechanical is thus converted into chemical force.‡

§ 15. Reverting now to the solidified globe, in whose superficial portions and in the surrounding gases and vapors were present all the chemical elements with which we have to do, it is necessary to consider briefly its physical and its chemical condition at this early period.

The formation of a crust at the surface of the viscid layer which still enveloped the solidified mass of the globe, as conceived by Hopkins, is readily admissible; but that this process commenced when the remaining envelope of liquid matter was yet so deep that the refrigeration up to the present time has not been sufficient for its entire solidification is not probable. Such a crust on the cooling superficial layer would, from the contraction consequent on the further refrigeration of the liquid stratum beneath, become more or less depressed, corrugated, and

* The elevated temperature of the interior of the globe would probably offer no obstacle to the development of magnetism. In a recent experiment of M. Trève, communicated by M. Faye to the French Academy of Sciences, it was found that molten cast iron when poured into a mold, surrounded by a helix which was traversed by an electric current, became a strong magnet when liquid at a temperature of 1,300° C., and retained its magnetism while cooling. (*Comptes-Rendus de l'Académie des Sciences*, February, 1869.)

† T. S. Hunt, Thoughts on Solution, American Journal of Science, [2,] xix, 100.

‡ Bakerian Lecture for 1863, L. E. and D, Philosophical Magazine, February, 1864.

broken up, thus causing the extravasation of the yet unsolidified portion, which would contribute to the vast amount of mineral matter brought within the chemical influences of the surrounding atmosphere. Further contraction from cooling would render this material more or less porous and permeable, preparing it for that process of combined mechanical and chemical disintegration which would result from the action of the acid liquids afterwards to be precipitated from the atmosphere.

§16. We have next to consider the chemical constitution of this irregular surfaced and broken-up crust of anhydrous and primitive igneous rock, which is now everywhere buried beneath the products of its disintegration. It is evident that, with the exception of those which were still in a gaseous form, it must have contained all the elements which now make up the known rocks of the earth's crust. If we conceive these, together with the air, the ocean, and its dissolved salts, now to react upon each other under the influence of an intense heat, it will enable us to form some notion of the chemical relations of the elements of the globe at the time when they were cooling down from that condition of igneous vapor which we suppose to have been that of our planet at an early stage in its history. To the chemist it is evident that from such a process applied to our globe would result the oxidation of all carbonaceous matter, the conversion of all carbonates, chlorides, and sulphates, into silicates, and the separation of the carbon, chlorine and sulphur in the form of acid gases, which, with nitrogen, watery vapor, and an excess of oxygen, would form an exceedingly dense atmosphere. The resulting fused mass would contain all the bases as silicates, and would probably nearly resemble in composition certain furnace-slags or basic volcanic glasses. Such we may conceive to have been the nature of the primitive igneous rock, and such the composition of the primeval atmosphere, which must have been one of very great density. Under the pressure of a high barometric column condensation would take place at a temperature much above the present boiling point of water, and the lower levels of the half-cooled crust would be drenched with a highly heated solution of hydrochloric acid, whose decomposing action would be powerfully aided by the temperature. The formation of chlorides of the various bases, and the separation of silica, would go on until the affinities of the acid were satisfied, while there would result a sea-water holding in the solution, besides the chlorides of sodium, calcium, and magnesium, salts of aluminum and other metallic bases. At a later period the gradual combination of oxygen with sulphurous acid would eliminate this from the atmosphere in the form of sulphuric acid. The atmosphere being thus deprived of its volatile compounds of chlorine and sulphur, would approach to that of our own time, but differ in its much greater amount of carbonic acid. It will be remarked that from the affinities which would come into play in the conditions above supposed, all the elements, with the exception of the noble metals, nitrogen, chlorine, the related haloids, and the hydrogen combined with these, would be united with oxygen. The volatility of gold, silver, and platinum, would keep them still in a gaseous condition at temperatures where silicon, and with it the baser metals, were precipitated in the form of oxides.

§17. The process just described ceased with the separation from the air of the compounds of sulphur and chlorine, and then commenced the second stage in the action of the atmosphere on the earth's crust, by which, under the influence of carbonic acid and moisture, its complex aluminous silicates are converted into a hydrated silicate of alumina or clay; while the separated lime, magnesia, and alkalies, being changed into bicarbonates, are conveyed to the sea in a state of solution.

The first effect of these dissolved carbonates would be to precipitate the dissolved alumina and the heavy metals, after which came the decomposition of the chloride of calcium and the formation of carbonate of lime and chloride of sodium. This action of carbonic acid is still going on at the earth's surface, slowly breaking down and destroying the hardest rocks, and, aided by mechanical processes, transforming them into clays; although the action, from the comparative rarity of carbonic acid in the atmosphere, is now less energetic than in earlier times, when the abundance of this gas, and a higher temperature, favored the chemical decomposition of the rocks. But now, as then, every clod of clay formed from the decay of a crystalline rock corresponded to an equivalent of carbonic acid abstracted from the atmosphere, and to equivalents of carbonate of lime and common salt formed from the chloride of calcium of the sea-water.

It is very instructive, in this connection, to compare the composition of the waters of the modern ocean with that of the sea in ancient times, whose composition we learn from the fossil sea-waters which are still to be found in certain regions, imprisoned in the pores of the older stratified rocks, and are the source of many of our saline mineral waters*. These are vastly richer in salts of lime and magnesia than those of the present sea, from which have been separated, by chemical processes, all the carbonate of lime of our limestones, with the exception of that derived from the sub-aërial decay of calcareous and magnesian silicates belonging to the primitive crust.

§ 18. The gradual removal, in the form of carbonate of lime, of the carbonic acid from the primeval atmosphere, has been connected with great changes in the organic life of the globe. The air was doubtless at first unfit for the respiration of warm-blooded animals, and we find the higher forms of life coming gradually into existence as we approach the present period of a purer air. Calculations based upon the probable amount of limestone in the earth's crust, lead us to conclude that the amount of carbon thus removed in the form of carbonic acid has been so enormous, that we must suppose the earlier forms of air-breathing animals to have been peculiarly adapted to live in an atmosphere which would probably be too impure to support modern reptilian life.

Growing plants under the stimulus of light possess, as is well known, the power to absorb carbonic acid, appropriating the carbon and liberating oxygen. The importance of this agency in purifying the primitive atmosphere was long since pointed out by Brongniart, and our great stores of fossil fuel have been derived from the decomposition, by the ancient vegetation, of the excess of carbonic acid of the early atmosphere, which, through this agency, was exchanged for oxygen gas. In this connection the vegetation of former periods presents the curious phenomenon of plants allied to those now growing beneath the tropics flourishing within the polar circles. Many ingenious hypotheses have been proposed to account for the warmer climate of earlier times, but are at best unsatisfactory, and it would appear that the true solution of the problem may be found in the constitution of the early atmosphere, when considered in the light of Dr. Tyndal's beautiful researches on radiant heat. He has found that the presence of a few hundredths of carbonic acid gas in the atmosphere, while offering almost no obstacle to the passage of the solar rays, would suffice to prevent almost entirely the loss by radiation of obscure heat.

The aqueous vapor which our atmosphere contains exerts a powerful

* T. S. Hunt. Contributions to the Chemistry of Natural Waters, American Journal of Science, [2.] XXXIX, 184.

influence of the same kind, allowing the sun's rays to reach the earth, but preventing to a great extent the loss by radiation of the heat thus communicated. When, however, the supply of heat from the sun is interrupted at night, the radiation which goes on into space causes the precipitation of a great part of the watery vapor from the air, and the earth, being thus deprived of its protecting shield, becomes more and more rapidly cooled. If now we could suppose the atmosphere to be mingled with some permanent gas which should possess an absorptive power like that of aqueous vapor, this cooling process would be in a great measure arrested, and an effect would be produced similar to that of a screen of glass, which keeps up the temperature beneath it, both directly by preventing the escape of radiant heat, and indirectly by hindering the condensation of the aqueous vapor in the air confined beneath. Such a gas is carbonic acid, and the large amount of it which existed in the atmosphere during former geological periods must have aided greatly to maintain the elevated temperatures which then existed at the earth's surface. Without doubt the greater extent of sea and the absence or rarity of high mountains contributed much to the mild climate of former geologic ages; but to these must be added the influence of the whole of the carbon since condensed in the forms of carbonate of lime and coal, which then existed as a transparent and permanent gas mingled with the atmosphere surrounding the earth, and protecting it like a dome of glass. To this effect of carbonic acid it is possible that other gases may have contributed. The ozone which is mingled with the oxygen set free from growing plants, and the marsh-gas which is now evolved from decomposing vegetation, may, by their absorptive powers, which are far greater than that of carbonic acid, have contributed greatly to maintain a high temperature at the earth's surface in early times.*

§ 19. The part which vegetation has played in the chemical history of the globe has not been limited to the purification of the atmosphere. It seems to have been the great agent through which solar force has effected a partial deoxidation of the thoroughly burned or oxidized materials of the primitive world. By means of growing plants carbonic acid and water are reduced, giving rise to the various forms of carbon and to hydrocarbonaceous bodies, and these have been the agents by which the sulphates of the metals have been deoxidized, and sulphur, native metals, and metallic sulphides produced. It is moreover by the reducing action of decaying organic matters that the peroxide of iron is partially reduced and removed in a soluble form from sediments, to be afterwards deposited in the form of iron ore. The evidences of this reducing and dissolving action of organic matter are met with not only in the fireclays and iron-stones of the carboniferous system, and among secondary, tertiary, and modern deposits, but on a grand scale in the Laurentian system, where great thicknesses of sediments are found almost destitute of iron, while beds of iron ore more extensive than at any subsequent periods are evidences of the abundance of organic matters at that early time. If these are not more frequently preserved in the form of anthracite and graphite, it is because the amount of peroxide of iron diffused through the sediments of the period furnished the oxygen necessary for the oxidation of the carbon. Inasmuch as the ores of these old rocks, in their present forms of hematite and magnetite, are very insoluble, and represent so much iron withdrawn from the terrestrial circulation, it is evident that the proportion of this element, existing in a dif-

* T. S. Hunt, On the Earth's Climate, etc., American Journal of Science, [2,] xxxvi, 396, 1863.

fused and oxidized state in recent sediments, must be less in those of more remote times.*

To the chemist the presence of graphite, or of a metallic sulphide in a rock, affords clear evidences of the intervention of organic life; and these indirect evidences are met with not only in the oldest known stratified rocks, those of the Laurentian system, but in the eruptive diorites, which rise from beneath them, and are pyritiferous. The presence of graphite, native iron, and sulphurets in most aërolites, not to mention the hydrocarbonaceous matters which they sometimes contain, tells us in unmistakable language that these bodies come from a region where vegetable life has performed a part not unlike that which still plays on our globe, and even lead us to hope for the discovery in them of organic forms which may give us some notion of life in other worlds than our own.

§20. Animal life has played in the chemical history of our planet a part much less important than vegetation, since it is entirely dependent for support upon the products elaborated for it by plants, and by chemical forces. Thus, although many limestones are made up chiefly, and even wholly of the calcareous remains of marine animals, these did no more than appropriate from the water the carbonate of lime generated by the chemical actions explained in §17. If the waters of the present ocean do not deposit carbonate of lime, it is simply because the amount of it now generated by the slow decomposition of the solid rocks is not more than is required for the living organisms which it contains. Let these become extinct and the supply of carbonate of lime, which would still continue, would soon cause deposits of precipitated carbonate of lime. Such a condition of things existing in past ages, in limited basins, has given rise to sediments of this kind, which constitute some of the finest statuary marbles.

The waters charged with the products of the sub-aërial decay of rocks, convey to the sea, as we have seen, bicarbonates of alkalies, lime, and magnesia; but from the reaction of these on the chloride and sulphate of calcium in the ocean waters carbonate of lime alone separates, since bicarbonate of magnesia decomposes chloride of calcium with formation of magnesian chloride. When, however, in a closed sea-basin all of the chloride of calcium is decomposed, the chloride of magnesium is attacked by the alkaline carbonates, and the resulting carbonate of magnesia is separated, mixed with the carbonate of lime which had accompanied these.

When into a similar closed basin, or an evaporating salt lake in a dry region, holding sulphate of magnesia, there is conveyed a water charged with bicarbonate of lime, there results a double decomposition, giving rise to sulphate of lime and bicarbonate of magnesia. The latter, being the more soluble salt, remains dissolved, while the sulphate of lime crystallizes out in the form of gypsum, but at a later period is deposited as a hydrated carbonate of magnesia, generally mixed with carbonate of lime. To effect this reaction it is necessary that there should be present such an excess of carbonic acid as to keep the magnesia in the condition of bicarbonate until the gypsum has crystallized out, inasmuch as dissolved sulphate of lime is readily decomposed by carbonate of magnesia. This condition can only be attained by especial precautions in the atmosphere of our period; but by operating in an atmosphere more highly charged with carbonic acid, the production of gypsum and magnesian carbonate by this reaction is readily effected. We may hence conclude that it was the more highly carbonated atmosphere of early periods which

* Geology of Canada, 1863, p. 573.

favored the accumulation of the great beds of gypsum and magnesian limestones which generally accompany the salt deposits of past geological periods. The hydrated magnesian carbonate, whether the concomitant of gypsum, as in this case, or of chloride of sodium, as in the former reaction, unites chemically with the associated carbonate of lime, and gives rise to dolomite or magnesian limestone.*

§ 21. The action of carbonated alkaline waters on the salts of the sea under ordinary conditions thus gives rise to carbonate of lime, and it is only under peculiar circumstances that magnesian carbonate is separated. The case is, however, changed with silicated alkaline waters coming from deep seated silicated rocks, which undergo a decomposition without the intervention of the atmospheric air, and hold dissolved silicates of alkalies and of lime. These reacting on the magnesian salts dissolved in sea-water give rise to magnesian silicates, which are very insoluble. Hence we frequently find deposits of magnesian silicates in sediments, while silicates of lime are comparatively rare. In the solubility of bicarbonate of magnesia and the insolubility of the corresponding lime salt, and in the insolubility of magnesian silicate and the solubility of silicate of lime, we find a simple explanation of the geological relation of calcareous and magnesian silicates and carbonates.†

§ 22. The relations of the alkalies, potash and soda, require some consideration in this connection. The silico-aluminous compounds of potash possess a much greater degree of stability than those of soda. This is exemplified in the case of rocks which contain, side by side, orthoclase and albite, or oligoclase, when it is often found that the soda-feldspar has undergone decomposition from a loss of a portion of its alkali and partial disintegration, while the orthoclase or potash-feldspar remains unchanged. It is well known that waters holding large portions of potash salts in solution, exchange the potash for soda when filtered through a stratum of earth in which the amount of potash is, nevertheless, as great or greater than the soda; and we find that in natural spring-waters, which often contain considerable amounts of alkaline carbonates, the proportion of potash to the soda is as small as in the ocean. Surface-waters bearing the unfiltered wash of the land carry considerable portions of potash to the sea, but it is constantly removed, partly, at least, by the agency of fucoids, which, as Forchammer has shown, like land-plants, take up large amounts of potash, and subsequently, by their decay in contact with the argillaceous mud, restore the alkali in an insoluble form to the earth. The formation of glauconite, a peculiar silicate rich in potash, which has been going on in the bottom of the sea from a very early period to the present time, has also been constantly withdrawing the potash from the ocean, so that soda is still the predominant base in its waters.

§ 23. The changes of silicated rocks under the influence of water, carbonic acid, and the products of decaying organic matter, present several points of interest. The chemical decomposition of feldspars consists in the removal of their protoxide bases, alkalies, and lime, together with a portion of silica, leaving as a final result a hydrous silicate of alumina or clay. This change is favored by mechanical division, and Daubrée has shown that by the prolonged attrition of the particles of granite under water, the softer and cleavable feldspar is, in great part, reduced to an impalpable powder, while the uncleavable quartz forms rounded grains of sand, the water at the same time dissolving from the feldspar a

* T. S. Hunt, On the Salts of Lime and Magnesia. American Journal of Science, [2,], xlii, 49.

† T. S. Hunt, American Journal of Science, [2,] xl, 49.

certain portion of alkali and silica. The soda-feldspars, being more easily decomposed and disintegrated by atmospheric influences, are broken up by mechanical agencies more readily than the potash-feldspar. The same is true of silicates like hornblende and pyroxene, which are less hard than the feldspars. From the mechanical and chemical disintegration of ordinary crystalline rocks, which consist chiefly of these various minerals, together with quartz, there will result a coarse sandy sediment, in which quartz with more or less orthoclase will prevail, while the finer mud will contain only the more minutely divided particles of these, together with partially decomposed soda-feldspar, clay, and the comminuted hornblende and pyroxene.

§ 24. This process is evidently one which must go on in the wearing away of rocks by aqueous agency, and explains the fact that while quartz, or an excess of combined silica, is, for the most part, wanting in rocks which contain a large portion of alumina, it is generally abundant in those rocks in which potash-feldspar predominates. The coarser and more silicious sediments are readily permeable to infiltrating waters, which gradually remove from them the soda, lime, and magnesia which they still contain, and, if organic matters intervene, the oxide of iron, leaving at last little more than silica, alumina, and potash, the elements of granite, trachyte, gneiss, and mica-schist. On the other hand, the finer sediments, whose origin, simultaneous with the coarser, we have just explained, resisting the penetration of waters, will retain all their soda, lime, magnesia, and iron-oxide, and containing an excess of alumina, with a small amount of silica, may, by their metamorphism, give rise to basic lime and soda-feldspars, and to pyroxene and hornblende—the elements of diorites and dolerites.

§ 25. The disintegration of alkaliferous rocks, however, frequently takes place under such conditions as to be more mechanical than chemical, and it may often happen that sediments still retaining a considerable amount of combined soda become mingled with carbonates of lime and magnesia. The reaction which then goes on between the liberated alkaline silicate and these earthy carbonates gradually effects the conversion of these into silicates, while the alkali is eliminated in the form of soluble carbonate of soda, giving rise to alkaline mineral waters, which, as I have shown, are abundantly generated in sediments where feldspathic matters and earthy carbonates are intermingled. It is only from rocks destitute of these carbonates that silicated alkaline waters can issue.

§ 26. A decomposition more exclusively chemical is observed particularly among the crystalline schists of tropical and semi-tropical regions, where a process of disintegration often destroys the cohesion of the rocks to a considerable depth. This change, which has been but imperfectly studied, is probably dependent in great part on the action of the soluble products of vegetable decomposition, aided by the elevated temperature. It, however, requires careful investigation; and a consideration of the causes which have induced it, and the extent to which it may have in former periods prevailed on the earth's surface, is of great geological importance, since the immense erosion of which geognosy affords us evidence, and which seems so difficult to explain if we conceive the rocks to have been as hard as we now find them in many regions, becomes more easily intelligible if we suppose the cohesion of the crystalline rocks to have been previously much weakened by decay.

§ 27. The operation of the mechanical and chemical agencies which preside over the disintegration of pre-existing rocks naturally divides the insoluble products into two types, approaching in chemical composition, as we have shown, to granites, gneiss, and mica-schist, on the one hand,

and to diorites and dolerites on the other. These correspond to the two classes of igneous rocks designated by Bunsen as the trachytic and pyroxenic types.

§ 28. There is, however, a third source of silicated rocks, to which some allusion has already been made in speaking of the production of magnesian silicates by direct precipitation, as the result of chemical changes in solutions. In this way have been formed, besides these and related protoxide silicates, other silicates, including alumina. This base in certain conditions as yet but imperfectly understood, passes into solution in water, and has given rise to complex silicates, including protoxide bases. As I have elsewhere expressed it, not only steatite, pyroxene, hornblende, and serpentine, but chlorite and, in many cases, garnet and epidote, have had their origin in the crystallization and molecular re-arrangement of natural silicates, generated by chemical processes in aqueous solutions at the earth's surface. To these must be added other silicates, containing alkalies, chiefly potash, such as glauconite, and a hydrous silicate of alumina and potash which has the composition of pinite or agalmatolite and forms beds in the sedimentary rocks of different geological periods. Evidences abound of the solution of alumina, and of the generation, as chemical precipitates, of various aluminiferous silicates. These, like the similarly-formed protoxide silicates, are in most, if not all cases, highly basic, and moreover, from the mechanical conditions of their production and deposition, are found associated and even intermingled with the finely-divided basic sediments of mechanical origin. The aluminous silicates thus formed, though mineralogically important, are probably small in amount when compared with the great mass of argillaceous sediments.

§ 29. The chemical changes which are wrought in the silicated rocks during their mechanical disintegration are, as we have seen, chiefly the elimination of the alkalies, especially the soda, in a soluble form from its aluminous compounds, and the separation and accumulation of the oxide of iron. The decomposition of the silicates of lime and magnesia which takes place is, to a great extent, compensated for by the regeneration of similar compounds by the reaction already explained, but the mean composition of the argillaceous sediments of any geological epoch will depend not only upon the age of a formation, but upon the number of times which its materials have been broken up, and the length of the periods during which they have been exposed, in an unmetamorphosed condition, to the action of water, carbonic acid, and vegetation. If, however, we may assume that this action, other things being equal, has on the whole been most complete in the newest formations, it is evident that the chemical and mineralogical composition of different systems of rocks must vary with their antiquity, so that we may find in their comparative study a guide to their respective ages. Silicious deposits, and chemical precipitates, like the carbonates and silicates of lime and magnesia, may exist, with similar characters, in the geological formations of any age,* not only forming beds apart, but mingled with the less permeable silico-aluminous sediments of mechanical origin. Inasmuch as the chemical agencies giving rise to these compounds were then most active, they may be expected in greatest abundance in the rocks of the earlier periods. In the case of the more permeable and more highly silicious sediments already noticed, (§ 24,) whose principal elements are silica, alumina, and alkalies, the deposits of different ages will be marked chiefly by a progressive diminution in the amount of potash and in the disappearance of the soda which they contain. In the oldest or least

* Geology of Canada, Report, 1866, page 230.

lixiviated rocks the proportion of alkali will be nearly or quite sufficient to form orthoclase or albite with the whole of the alumina present, but as the alkali diminishes, a portion of the alumina will crystallize, upon the metamorphism of the sediments, in the form of a potash-mica, such as muscovite or margarodite. While the oxygen-ratio between the alumina and the alkali in the feldspars just named is 3:1, it becomes 6:1 in margarodite and 12:1 in muscovite. The appearance of these micas in an aluminous rock denotes, then, a diminution in the amount of alkali, until in some strata the feldspar almost entirely disappears, and the rock becomes a quartzose mica-schist. In sediments still further deprived of alkali, metamorphism gives rise to schists filled with crystals of kyanite or of andalusite, simple silicates of alumina, into which alkalies do not enter, at least in noticeable quantities; but, in case the sediment still retains oxide of iron, staurolite and iron-garnet take their place. The matrix of all these minerals is generally a micaceous schist. The last term in this exhaustive process appears to be represented by the disthene and pyrophyllite rocks which occur in some regions of crystalline schists. In conformity with what has just been pointed out, it will be seen that these aluminous silicates destitute of alkalies do not occur in the oldest known sediments; in those of the Laurentian system, in which also mica is found in comparatively small quantities, nearly all the alumina present being in the form of orthoclase or albite.*

§ 30. By metamorphism in geology is understood the change of chemical and mechanical sedimentary deposits into crystalline stratified rocks. The conversion of these sediments into definite mineral species has been effected in two ways: First, by molecular changes—that is to say, by a crystalline arrangement of particles of definite compounds previously formed; and, secondly, by chemical reactions between the elements in heterogeneous sediments, giving rise to new compounds, which become crystalline in their turn. Pseudomorphism, which is the change of one mineral species into another by the introduction or the elimination of some element or elements, presupposes metamorphism, since only definite mineral species can be the subjects of this process. To confound metamorphism with pseudomorphism, as Bischof and others after him have done, is therefore an error. It may be further remarked that although certain pseudomorphic changes may take place in some mineral species existing in veins and near to exposed surfaces, the alteration of great masses of silicated rocks by such a process is as yet an unproved hypothesis.

§ 31. The cases of local metamorphism in proximity to intrusive rocks go far to show, in opposition to the views of certain geologists, that heat has been one of the necessary conditions of the chemical change. The source of this heat is generally admitted to be from below, but to the hypothesis of alteration by ascending heat Naumann has objected that the inferior strata in some cases escape change, and that, in descending, a certain plane limits the metamorphism, separating the altered strata above from the unaltered strata beneath, there being no apparent transition between the two. This, taken in connection with the well-known fact that in many cases the intrusion of igneous rocks causes no apparent change in the adjacent unaltered sediments, shows that heat and moisture are not the only conditions of metamorphism. I showed, by experiments in 1857, that, in addition to these conditions, certain

* For a discussion of this subject see my paper on The Chemical and Mineralogical Relations of Metamorphic Rocks, Dublin Quarterly Journal of Science, July, 1863; also Geology of Canada, 1863, page 561, and chap. XIX, of the same work.

chemical reagents might be necessary, and that water impregnated with alkaline carbonates and silicates would, at a temperature not above 100° centigrade, produce chemical reactions among the elements of many sedimentary rocks, dissolving silica and generating various insoluble silicates.* Subsequent experiments by Daubrée confirmed these results of mine, and both together showed the agency of heated alkaline waters to be sufficient to effect the metamorphism of sediments by the two modes already mentioned, namely, by molecular changes and by chemical reactions.

§ 32. Daubrée further showed, by his observations on the thermal alkaline spring at Plombières, that its waters, at a temperature of 70° centigrade, had in the course of centuries given rise to the formation of zeolites and other crystalline silicated minerals among the bricks and mortar of the old Roman baths. The influence of similar waters may account for many cases of local metamorphism, but is utterly inadequate to explain the complete and universal alteration of great areas of sedimentary rocks, embracing many hundreds or thousands of square miles. On the other hand, the study of the origin and distribution of mineral springs shows that alkaline waters, whose action in metamorphism I first pointed out, and whose efficient agency Daubrée has since so well shown, are confined to certain sedimentary deposits and to definite stratigraphical horizons, above and below which saline waters wholly different in character are found impregnating the strata. This fact offers a simple solution of the difficulty advanced by Naumann, and a complete explanation of the theory of metamorphism of deeply-buried strata by the agency of ascending heat, which is operative in producing chemical changes only in those strata in which soluble alkaline salts are present.

§ 33. We have said that the metamorphism of sediments includes both chemical and crystallogenic changes. The gradual transformation of amorphous precipitates under water into crystalline aggregates, so often observed in the laboratory, appears to depend upon partial solution and re-deposition of the material, which must not be entirely insoluble in the surrounding liquid. If the solvent power of this be reduced, the dissolved portions are deposited on certain particles rather than others. By a subsequent exaltation of the solvent power of the liquid, solution of a further portion takes place, and this, in its turn, is deposited around the nuclei already formed, which are thus augmented at the expense of the smaller particles, until these at length disappear, being gathered to the crystalline centers. Such a process, which has been studied by H. Deville, suffices, under the influence of the changing temperature of the seasons, to convert many fine precipitates into crystalline aggregates, by the aid of liquids of slight solvent powers. A similar agency may be supposed to have effected the crystallization of buried sediments, and changes in the solvent power of the permeating water might be due either to variations of temperature or of pressure. Simultaneously with this process one of chemical union of heterogeneous elements may go on, and in this way, for example, we may suppose the carbonates of lime and magnesia become united to form dolomite or magnesian limestone. (§ 20.)

§ 34. When the sedimentary strata have thus been rendered crystalline by metamorphism, their permeability to water and their alterability thereby become greatly diminished; and it is only when again broken down by mechanical agencies to the condition of soils and sediments that they once more become subject to the chemical changes which have

* T. S. Hunt, American Journal of Science, [2,] xxiii, 407; xxv, 287–437.

been described in § 23. While the crystalline stratified rocks are but slightly porous the unaltered strata hold large quantities of water in their pores. The mean of thirty-six determinations upon sandstones, shales, limestones, and dolomites from twenty-five different localities among the unaltered paleozoic sediments of Canada showed that 7.75 volumes of water were held in 100 volumes of the thoroughly-moistened rock. The proportion varied from less than 1.0 per cent. in the more compact limestones, to 10.0 and even 21.0 per cent. in the sandstones, an amount which is greatly exceeded in some more recent limestones.* A large proportion of the ocean's waters is thus imprisoned in the vast volume of unaltered sediments, and set free when these become metamorphosed, a process which is attended with a corresponding reduction of volume. In addition to this, moreover, the clays and other hydrated silicates lose a large part of their chemically-combined water during metamorphism, and become changed into crystalline compounds of increased density. This becomes obvious when we compare the specific gravity of such species as garnet, epidote, chloritoid, staurolite, andalusite and kyanite with that of the unaltered sediments in the midst of which they are generated. From this condensation, then, as well as from the mechanical contraction consequent upon the expulsion of water, the metamorphism of sediments is attended with a very considerable diminution of bulk, which is not without geological significance. It results from the experiments of Sorby (§ 14) that such chemical changes as are accompanied by condensation or diminution of volume are favored and accelerated by pressure, which may thus become a direct agent in promoting metamorphism as well as solution.

§ 35. The crystallization which takes place in sedimentary rocks not unfrequently effaces more or less completely the traces of their stratified and sedimentary origin, as is seen, for example, in many gneisses, which are scarcely distinguishable from granite. The study of such rocks, moreover, affords abundant proof that this alteration has been attended with such a softening that the material has been molded by pressure, forced into fissures or openings in less fusible or less heated strata, and thus taken the form of what is designated as eruptive rocks. The action of heat upon sedimentary rocks is not, however, confined to condensation, crystallization, and softening; strata in which carbonates, sulphates, chlorides, and carbonaceous substances are mingled with silicious and argillaceous matters, will, at a sufficiently-elevated temperature, in the presence of water, undergo such changes as must liberate carbonic acid, hydrochloric acid, and sulphuretted hydrogen, which are the common gaseous accompaniments of volcanic action. From these considerations we are led to a rational theory of volcanic and eruptive rocks, which we conceive to have their seat, not in an uncongealed portion of the once liquid globe, but in the more deeply-buried portions of that disintegrated crust whose origin has been explained in § 14.

§ 36. The history of this theory forms an interesting chapter in geology. As remarked by Humboldt, a notion that volcanic phenomena have their seat in the sedimentary formations, and are dependent on the combustion of organic substances, belongs to the infancy of geology. To this period belong the theories of Lémery and Breislak, (*Cosmos*, v. 443; Otte's translation.) Keferstein, in his *Naturgeschichte des Erdkörpers*, published in 1834, maintained that all crystalline non-stratified rocks, from granite to lava, are products of the transformation of sedimentary strata, in part very recent, and that there is no well-defined

* Geological Report of Canada, 1866, p. 283.—American Journal of Science, [2,] xxxix, 183.

line to be drawn between neptunian and volcanic rocks, since they pass into each other. Volcanic phenomena, according to him, have their origin, not in an igneous fluid center, nor in an oxidizing metallic nucleus, (Davy, Daubeny,) but in known sedimentary formations, where they are the result of a peculiar kind of fermentation, which crystallizes and arranges in new forms the elements of the sedimentary strata, with an evolution of heat as a result of the chemical process, (*Naturgeschichte*, vol. i, p. 109; also *Bulletin de la Société Géologique de France*, [1], vol. vii, p. 197.) In commenting upon these views, (*American Journal of Science*, July, 1860,) I have remarked that, by ignoring the incandescent nucleus as a source of heat, Keferstein has excluded the true exciting cause of the chemical changes which take place in the buried sediments. The notion of a subterranean combustion or fermentation, as a source of heat, is to be rejected as irrational.

§ 37. A view identical with that of Keferstein, as to the seat of volcanic phenomena, was soon after put forth by Sir John Herschel, in a letter to Sir Charles Lyell, in 1836, (*Proceedings of the Geological Society of London*, ii, 548.) Starting from the suggestion of Scrope and Babbage, that the isothermal horizons in the earth's crust must rise as a consequence of the accumulation of sediments, he insisted that deeply-buried strata will thus become crystallized by heat, and may eventually, with their included water, be raised to the melting point, by which process gases would be generated, and earthquakes and volcanic eruptions follow. At the same time the mechanical disturbance of the equilibrium of pressure, consequent upon a transfer of sediments, while the yielding surface reposes on matters partly liquified, will explain the movements of elevation and subsidence of the earth's crust. Herschel was probably ignorant of the extent to which his views had been anticipated by Keferstein; and the suggestions of the one and the other seemed to have passed unnoticed by geologists until, in March, 1858, I reproduced them in a paper read before the Canadian Institute, (Toronto,) being at that time acquainted with Herschel's letter, but not having met with the writings of Keferstein. I there considered the reactions which would take place under the influence of a high temperature in sediments permeated with water, and containing, besides silicious and aluminous matters, carbonates, sulphates, chlorides, and carbonaceous substances. From these, it was shown, might be produced all the gaseous emanations of volcanic districts, while from aqueo-igneous fusion of the various admixtures might result the great variety of eruptive rocks. To quote the words of my paper just referred to: "We conceive that the earth's solid crust of anhydrous and primitive igneous rock is everywhere deeply concealed beneath its own ruins, which form a great mass of sedimentary strata, permeated by water. As heat from beneath invades these sediments, it produces in them that change which constitutes normal metamorphism. These rocks, at a sufficient depth, are necessarily in a state of igneo-aqueous fusion; and in the event of fracture in the overlying strata, may rise among them, taking the form of eruptive rocks. When the nature of the sediments is such as generate great amounts of elastic fluids by their fusion, earthquakes and volcanic eruptions may result, and these—other things being equal—will be most likely to occur under the more recent formations." (*Canadian Journal*, May, 1858, vol. iii, p. 207.)

§ 38. The same views are insisted upon in a paper "On some points in Chemical Geology." (Quarterly Journal of the Geological Society, London, November, 1859, vol. xv, page 594,) and have since been repeatedly put forward by me, with further explanations as to what I have designated

above, *the ruins of the crust of anhydrous and primitive igneous rock.* This, it is conceived, must, by contraction in cooling, have become porous and permeable, for a considerable depth, to the waters afterward precipitated upon its surface. In this way it was prepared alike for mechanical disintegration, and for the chemical action of the acids, which, as shown in § 16, must have been present in the air and the waters of the time. It is, moreover, not improbable that a yet unsolidified sheet of molten matter may then have existed beneath the earth's crust, and may have intervened in the volcanic phenomena of that early period, contributing, by its extravasation, to swell the vast amount of mineral matter then brought within aqueous and atmospheric influences. The earth, air, and water thus made to react upon each other, constitute the first matter from which, by mechanical and chemical transformations, the whole mineral world known to us has been produced.

§ 39. It is the lower portions of this great disintegrated and water-impregnated mass which form, according to the present hypothesis, the semi-liquid layer supposed to intervene between the outer solid crust and the inner solid and anhydrous nucleus. In order to obtain a correct notion of the condition of this mass, both in earlier and later times, two points must be especially considered, the relation of temperature to depth, and that of solubility to pressure. It being conceded that the increase of temperature in descending in the earth's crust is due to the transmission and escape of heat from the interior, Mr. Hopkins showed mathematically that there exists a constant proportion between the effect of internal heat at the surface and the rate at which the temperature increases in descending. Thus, at the present time, while the mean temperature at the earth's surface is augmented only about one-twentieth of a degree Fahrenheit, by the escape of heat from below, the increase is found to be equal to about one degree for each sixty feet in depth. If, however, we go back to a period in the history of our globe when the heat passing upwards through its crust was sufficient to raise the superficial temperature twenty times as much as at present, that is to say, one degree of Fahrenheit, the augmentation of heat in descending would be twenty times as great as now, or one degree for each three feet in depth, (*Geological Journal*, viii, 59.) The conclusion is inevitable that a condition of things must have existed during long periods in the history of the cooling globe when the accumulation of comparatively thin layers of sediment would have been sufficient to give rise to all the phenomena of metamorphism, vulcanicity, and movements of the crust, whose origin Herschel has so well explained.

§ 40. Coming, in the next place, to consider the influence of pressure upon the buried materials derived from the mechanical and chemical disintegration of the primitive crust, we find that by the presence of heated water throughout them, they are placed under conditions very unlike those of the original cooling mass. While pressure raises the fusing point of such bodies as expand in passing into the liquid state, it depresses that point for those which, like ice, contract in becoming liquid. The same principle extends to that liquefaction which constitutes solution; where, as is with few exceptions the case, the process is attended with condensation or diminution of volume, pressure will, as shown by the experiments of Sorby, augment the solvent power of the liquid. Under the influence of the elevated temperature, and the great pressure which prevail at considerable depths, sediments should, therefore, by the effect of the water which they contain, acquire a certain degree of liquidity, rendering not improbable the suggestion of Scheerer, that the presence of five or ten per cent. of water may suffice, at temperatures approaching red-

ness, to give to a granitic mass a liquidity partaking at once of the character of an igneous and an aqueous fusion. The studies by Mr. Sorby of the cavities in crystals have led him to conclude that the constituents of granitic and trachytic rocks have crystallized in the presence of liquid water, under great pressure, at temperatures not above redness, and consequently very far below that required for simple igneous fusion. The intervention of water in giving liquidity to lavas, has, in fact, long been taught by Scrope, and notwithstanding the opposition of plutonists like Durocher, Fournet, and Rivière, is now very generally admitted. In this connection, the reader is referred to the *Geological Magazine* for February, 1868, page 57, where the history of this question is discussed.

§ 41. It may here be remarked that if we regard the liquefaction of heated rocks under great pressure, and in presence of water, as a process of solution rather than of fusion, it would follow that diminution of pressure, as supposed by Mr. Scrope, would cause not liquefaction, but the reverse. The mechanical pressure of great accumulations of sediment is to be regarded as co-operating with heat to augment the solvent action of the water, and as being thus one of the efficient causes of the liquefaction of deeply-buried sedimentary rocks.

§ 42. That water intervenes not only in the phenomena of volcanic eruptions, but in the crystallization of the minerals of eruptive rocks, which have been formed at temperatures far below that of igneous fusion, is a fact not easily reconciled with either the first or the second hypothesis of volcanic action, but is in perfect accordance with the one here maintained, which is also strongly supported by the study of the chemical composition of igneous rocks. These are generally referred to two great divisions, corresponding to what have been designated the trachytic and pyroxenic types, (§ 27,) and to account for their origin, a separation of a liquid igneous mass beneath the earth's crust into two layers of acid and basic silicates was imagined by Phillips, Durocher, and Bunsen. The latter, as is well known, has calculated the normal composition of these supposed trachytic and pyroxenic magmas, and conceives that from them, either separately or by admixture, the various eruptive rocks are derived; so that the amounts of alumina, lime, magnesia, and alkalies sustain a constant relation to the silica in the rock. If, however, we examine the analyses of the eruptive rocks in Hungary and Armenia, made by Streng, and put forward in support of this view, there will be found such discrepancies between the actual and the calculated results as to throw grave doubts on Bunsen's hypothesis.

§ 43. Two things become apparent from a study of the chemical nature of eruptive rocks: first, that their composition presents such variations as are irreconcilable with the simple origin generally assigned to them; and second, that it is similar to that of sedimentary rocks whose history and origin it is, in most cases, not difficult to trace. We have already pointed out (§ 27) how the natural operation of mechanical and chemical agencies tends to produce among sediments a separation into two classes, corresponding to the two great divisions above noticed. From the mode of their accumulation, however, great variations must exist in the composition of the sediments, corresponding to many of the varieties presented by eruptive rocks. The careful study of stratified rocks of aqueous origin discloses, in addition to these, the existence of deposits of basic silicates of peculiar types. Some of these are in great part magnesian; others consist of compounds like anorthite and labradorite, highly aluminous basic silicates, into which lime and soda enter, to the almost complete exclusion of magnesia and other bases; while in the masses of pinite or agalmatolite rock we have a similar aluminous

silicate, in which lime and magnesia are wanting, and potash is the predominant alkali, (§ 28.) In such sediments as these just enumerated we find the representatives of eruptive rocks like peridotite, phonolite, leucitophyre, and similar rocks, which are so many exceptions in the basic group of Bunsen. As, however, they are represented in the sediments of the earth's crust, their appearance as exotic rocks, consequent upon a softening and extravasation of the more easy liquefiable strata of deeply-buried formations, is readily and simply explained.

§44. In this connection a few words may be said about the popular notion which makes granite the substratum of all stratified formations, and even identifies it with the supposed primitive crust of the globe. That this crust is everywhere concealed beneath its own ruins, and, moreover, that its composition must have been very different from granite, we have endeavored to explain, (§ 16.) The Laurentian, the oldest known system of rocks, includes in its vast volume great interstratified masses of gneiss, often closely resembling granite, and it is extremely probable that these, softened and extravasated, may form the eruptive granites which break through more recent systems of strata. These granitic gneisses are, however, clearly stratified, and hold, moreover, intercalated beds of quartzite and of limestone, often of great volume, and including the remains of an animal organism—the *Eozoon Canadense.* The predominance of feldspar, which gives the granitic character to the aluminous rocks of early periods, has already been explained in §29 as resulting from the great abundance of combined alkalies in these ancient rocks. The presence of quartz, an essential element alike in gneiss and granite, would suffice to show that granite is in all cases a secondary or derived rock, formed under aqueous influences—even had Sorby not shown that the minute crystal-cavities in the quartz of granitic rocks contain liquid water which must have been introduced at the time of crystallization. Quartz has not only never been met with as a result of igneous fusion, but it is clearly shown by the experiments of Rose that a heat even much less than that required for the fusion of quartz destroys it, changing it into a new substance, which differs both in chemical and physical properties from quartz. We have pointed out in §16 the chemical process by which it may be supposed that silica was set free from the primitive silicated mass, under conditions which would permit its conversion into quartz.

§45. The rocks mentioned in preceding sections are, as regards their geognostical relations, divided into stratified or indigenous and erupted or exotic rocks, the latter being looked upon as the results of the softening and displacement of the former. Besides these, it is necessary to distinguish a third kind of rock-masses, which, like the latter, occupy fissures in previously-formed rocks, but are unlike them in origin, and have been deposited from aqueous solutions. The most familiar form of these is met with in the vein-stones of quartz, calcite, barytine, and fluor, which are often the gangue of metallic ores. A careful study of the various kinds of veins and their relations leads us, however, to admit that almost all the mineral species which occur in the preceding classes of rocks may exist in vein-stones, which, from the mode of their production, we have designated endogenous rocks. Calcareous veins in the Laurentian rocks may contain all the mineral species of indigenous limestones, and quartzo-feldspathic veins are made up of aggregates which are familiarly designated as granites. To these, in fact, belong all those so-called granitic veins which are marked by containing fine crystallizations or rare mineral species. When, as is often the case, these marks

are wanting it is sometimes difficult to distinguish in hand-specimens between indigenous, exotic, and endogenous granites.

§46. The deposition of these mineral species from solution has doubtless taken place under considerable degrees of heat and pressure, which could only exist at great depths in the earth's crust. Waters charged with mineral elements by percolation through deeply-seated strata rise through fissures in these and deposit along the channels their dissolved matters, a process not so much the result of cooling as of that decrease of solvent power which must follow the diminution of pressure in accordance with Sorby's conclusions.*

§47. As pointed out in §17, the first precipitates from the water of the primeval sea must have contained oxidized compounds of most of the heavy metals. These early deposits, by mechanical division or by solution, became subsequently diffused, and entered into the composition of later sedimentary strata. Removed from these by watery solution, the metallic compounds have been, in different ages, brought to the surface to be deposited in some cases as oxides or carbonates, or reduced by the action of organic matters to the state of sulphurets or native metals, and mingled with the contemporaneous sediments in beds or in disseminated grains. During the subsequent alteration of the strata, these metallic matters, being taken into solution, have been re-deposited in fissures in the metalliferous strata, forming veins, or, ascending to higher beds, have given rise to metal-bearing veins in strata not themselves metalliferous. The metals of the sedimentary rocks are now, however, for the greater part, in the form of insoluble sulphurets, so that we have only traces of them in a few mineral springs, which serve to give a faint notion of the agencies at one time at work in the sediments and waters of the earth's crust. Like the iron, (§19) these metals have been in great part withdrawn from the terrestrial circulation. The frequent occurrence of these metals in waters which are alkaline from the presence of carbonate of soda, is significant, when taken in connection with the metalliferous character of certain dolomites, which probably owe their origin to the action of similar alkaline springs upon basins of sea-water, (§20.) The intervention of intense heat and fusion or sublimation to explain the origin of metallic ores is uncalled for. The solvent powers of water and of various saline, alkaline, and sulphuretted solutions at high temperatures, in connection with the notions above enunciated, will suffice to form the basis of a rational theory of metallic deposits.†

§48. The consideration of the nature and origin of endogenous rocks has led to a digression to discuss the theory of metalliferous veins, which the plan of this essay did not permit us to treat before. We now resume the line of inquiry followed from §36 to §43, and proceed to consider the phenomena of volanoes and earthquakes in accordance with the notions already put forward.

Violent movements of the earth's crust are confined to certain regions of the globe, which are at the same time characterized by volcanic

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* Of this a remarkable example was afforded in 1866 at Goderich, in Ontario, where, at a depth of 1,000 feet, a bed of rock-salt was met, from which for a time a saturated or rather supersaturated brine was obtained. As an evidence of this, I saw a cube of pure salt, one-fourth of an inch in diameter, which had formed upon and around a projecting point of an iron valve in the pump, above the surface of the ground. The liquid beneath a pressure of 1,000 feet of brine, equal to about 1,200 feet of water, or 36 atmospheres, having taken up more salt than it could hold at the ordinary pressure, deposited a portion of it as it reached the surface, and actually obstructed thereby the action of the pump. After a few months of pumping, however, the well ceased to afford a fully saturated brine.

† American Journal of Science, [2,] xxxi, 405, and xl, 213.

activity; from which it is reasonably inferred that the phenomena of earthquakes and volcanoes have a common origin. The discharge through openings in the earth's crust, of ignited stony matter, generally in a fused condition, and the disengagement of various gases and vapors, accompanied by movements of elevation or subsidence of considerable areas of the earth's surface, sometimes rapid and paroxysmal, and attended with great vibratory movements, are evidences of a yielding crust of solid rock resting upon an igneous and fluid mass below. To the same conditions are also to be ascribed the slow movements of portions of the earth's surface, shown in the rise and fall of continents in regions remote from centers of volcanic activity. The unequal tension of the yielding crust and the sudden giving way of the overstrained portions are probably the immediate cause of earthquake phenomena; the seat of these, according to the deductions of Mallet, is to be found at depths of from seven to thirty miles from the surface.

§ 49. A brief description of the phenomena of volcanoes will here be necessary. Volcanoes are openings in the earth's crust through which are discharged solid, liquid, and gaseous matters, generally in an intensely heated condition. Sometimes the ejected material is solid, and consists of broken, comminuted rock, or the so-called volcanic ashes. Oftener, however, it is discharged in a more or less completely fused condition, constituting lava, which is sometimes fluid and glassy, but more frequently pasty and viscid, so that it flows slowly and with difficulty. The ejected materials, whether liquid or solid, build up volcanic cones by successive layers—a fact which has been established by modern observers in opposition to the notion come down from antiquity, that volcanic hills are produced by an uprising or tumefaction of previously horizontal layers of rock by the action of a force from beneath. First among the gaseous products of volcanoes is watery vapor; water appears not only to be involved in all volcanic eruptions, but to be intimately combined with the lavas, to which, as Scrope has shown, it helps to give liquidity. The water at this high temperature is retained in combination under great pressure, but as this pressure is removed passes into the state of vapor, a process which explains the swelling up of lavas and their rise in the craters of the volcanoes. Besides watery vapor, carbonic and hydrochloric acid gases, and hydrogen, both free and combined with sulphur and with carbon, are products of volcanoes. The combustion of the inflammable gases in contact with air sometimes give rise to true burning mountains—a name which does not properly belong to such as give out only acid gases, steam, and incandescent rocky matters, which are incombustible.

§ 50. The escape of elastic fluids from lavas gives to them a cellular structure, but when slowly cooled under pressure, as seen in the dykes traversing the flanks of volcanoes, the stony materials assume a more solid and crystalline condition, and resemble the older eruptive rocks found in regions not now volcanic. These include granites, trachytes, dolerites, basalts, &c., and are masses of rock which, though extravasated after the manner of lavas, became consolidated in the midst of surrounding rocks, and consequently under considerable pressure, (§ 37.) Their presence marks either the lower portions of volcanoes whose cones have been removed by denudation, or outbursts of liquefied rock which never reached the surface. The escape of such matters, and the formation of volcanic vents, are but accidents in the history of the igneous action going on beneath the earth's surface. We shall, therefore, regard the extravasation of igneous matter, whether as lava or ashes at the surface, or as plutonic rock in the midst of strata, as, in its

wider sense, a manifestation of vulcanicity, and for the elucidation of our subject consider both those regions characterized by great outbursts of plutonic rock in former geologic periods and those now the seats of volcanic activity, which, in these cases, can generally be traced back some distance into the tertiary epoch. To begin with the latter, the first and most important is the great continental region which may be described as including the Mediterranean and Aralo-Caspian basins, extending from the Iberian Peninsula eastward to the Thian-Chan Mountains of Central Asia. In this great belt, extending over about ninety degrees of longitude, are included all the historic volcanoes of the ancient world, to which we must add the extinct volcanoes of Murcia, Catalonia, Auvergne, the Vivarais, the Eifel, Hungary, &c., some of which have probably been active during the human period.*

Besides the great region just indicated, must be mentioned that of our own Pacific slope, from Fuegia to Alaska, from whence, along the eastern shore of Asia, a line of volcanic activity extends to the terrible burning mountains of the Indian archipelago. Volcanic islands are widely scattered over the Pacific basin, and volcanoes burn amid the thick-ribbed ice of the Antarctic continent. The Atlantic area is in like manner marked by volcanic islands from Jan Mayen and Iceland to the Canaries, the Azores, and the Caribbean Islands, and southward to Ascension, St. Helena, and Tristan d'Acunha.

§ 51. The continents, with the exception of the two areas already defined, present no evidences of modern volcanic action, and the regions of ancient volcanic activity, as shown by the presence of great outbursts of eruptive rocks, are not less limited and circumscribed. In northern Europe the chain of the Urals, an area in central Germany, and one in the British Islands are apparent, and in North America there appear to have been but two volcanic regions in the paleozoic period—one in the basin of Lake Superior, and another, which may be described as occurring along either side of the Appalachian chain to the northeast, including the valleys of the lower St. Lawrence, Lake Champlain, the Hudson and Connecticut Rivers, and extending still further southward. The study of the various eruptive rocks of this region shows that volcanic activity in different parts of it was prolonged from the beginning of the paleozoic period till after its close.

§ 52. The theory of Keferstein and Herschel, explained in § 37, shows in what manner volcanic phenomena may be directly dependent on the accumulation of sedimentary strata. It has already been shown that both temperature and pressure combine to produce in the lower portions

* It is a most significant fact that this region is nearly co-extensive with that occupied for ages by the great civilizing races of the world. From the plateau of Central Asia, throughout their westward migration to the pillars of Hercules, the Indo-European nations were familiar with the volcano and the earthquake; and that the Semitic race were not strangers to the same phenomena, the whole poetic imagery of the Hebrew Scriptures bears ample evidence. In the language of their writers, the mountains are molten, they quake and fall down at the presence of the Deity, when the melting fire burneth. The fury of His wrath is poured forth like fire; He toucheth the hills and they smoke; while fire and sulphur come down to destroy the doomed cities of the plain, whose foundation is a molten flood. Not less does the poetry and the mythology of Greece and Rome bear the impress of the nether realm of fire in which the volcano and the earthquake have their seat, and their influence is conspicuous throughout the imaginative literature and the religious systems of the Indo-European nations, whose contact with these terrible manifestations of unseen forces beyond their foresight or control could not fail to act strongly on their moral and intellectual development, which would have doubtless presented very different phases had the early home of these races been the Australian or the eastern side of the American continent, where volcanoes are unknown and the earthquake is scarcely felt. (From a lecture before the Amer. Geographical Society, April, 1869.)

of the sedimentary material a condition of igneo-aqueous fusion. It would be foreign to our plan to discuss in this place the agencies which, from early geologic periods, have been effecting the transfer of sediments, alternately wasting and building-up continents. One, however, requires notice in this connection, namely, the contraction of sediments consequent upon chemical changes, as already explained in § 34, which must result in subsidence. Such an effect may also result from the extravasation of great volumes of liquefied rock, and in either case the depressed portion of the surface becomes a basin, in which sediments may subsequently accumulate, and by their weight upon the yielding stratum beneath continue the process of subsidence. While the lower and more fusible strata becomes softened, the great mass of the more silicious rocks, losing their porosity, become cemented into a comparatively rigid mass, and finally, as a result of the earth's contraction, or to counterbalance the depression of some other region, are uplifted as a hardened and corrugated continental mass, from whose irregular erosion results a mountainous region.*

§ 53. Those strata which, from their composition, yield, under the conditions just described, the most liquid products, are, it is conceived, the source of all plutonic and volcanic rocks. Accompanied by water, and by difficultly coercible gases, they are either forced among the fissures which form in the overlying strata, or find their way to the surface. The variations in the composition of lavas and their accompanying gases in different regions, and even from the same vent at different times, are strong confirmations of the truth of this view. As explained in § 39, the semi-liquid layer of water-impregnated material constitutes a plastic bed, upon which the stratified sediments repose. These, by their irregular distribution over different portions of the earth, determined, after a lapse of time, in the regions of their greatest accumulation, volcanic and plutonic phenomena. It now remains to show the observed relation of these phenomena, both in the earlier and later times, to great accumulations of sediment.

§ 54. If we look at the North American continent, we find along its northeastern portion evidences of great subsidence and an accumulation of not less than 40,000 feet of sediment along the line of the Appalachians from the Gulf of St. Lawrence southward, during the paleozoic period, and chiefly, it would appear, during its earlier and later portions. This region is precisely that characterized by considerable eruptions of plutonic rocks during this period, and for some time after its close. To the westward of the Appalachians, the deposits of paleozoic sediments were much thinner, and in the Mississippi valley are probably less than 4,000 feet in thickness. Conformably with this, there are no traces of plutonic or volcanic outbursts from the northeast region just mentioned throughout this vast paleozoic basin, with the exception of the region of Lake Superior, where we find the early portion of the paleozoic age marked by a great accumulation of sediments, comparable to that occurring at the same time in the region of New England, and followed or accompanied by similar plutonic phenomena. Across the plains of northern Russia and Scandinavia, as in the Mississippi valley, the paleozoic period was represented by not more than 2,000 feet of sediments, which still lie undisturbed, while in the British Islands 50,000 feet of paleozoic strata, contorted and accompanied by igneous rocks,

* For a discussion of this subject and the theory of mountains, including the views of Professor James Hall, see the author on *American Geology*, American Journal of Science, [2] xxi, 406.

attest the connection between great accumulation and plutonic phenomena.

§ 55. Coming now to modern volcanoes, we find them in their greatest activity in oceanic regions, where subsidence and accumulation are still going on. Of the two continental regions already pointed out, that along the Mediterranean basin is marked by an accumulation of mesozoic and tertiary sediments, 20,000 feet or more in thickness. It is evident that the great mountain zone, which includes the Pyrenees, the Alps, the Caucasus and the Himalayah, was, during the later secondary and tertiary periods, a basin in which vast accumulations of sediments were taking place, as in the Appalachian belt during the paleozoic times. Turning now to the other continental region, the American Pacific slope, similar evidences of great accumulations during the same periods are found throughout its whole extent, showing that the great Pacific mountain belt of North and South America, with its attendant volcanoes, is, in the main, the geological equivalent or counterpart of the great east and west belt of the eastern world.

It is to be remarked that the volcanic vents are seldom immediately along the lines of greatest accumulation, but appear around and at certain distances therefrom. The question of the duration of volcanic activity in a given region is one of great interest, which cannot, for want of time, be considered here. It appears probable that the great manifestations of volcanic force belong to the period of depression of the area of sedimentation, if we may judge from the energy and copiousness of the eruptions of island volcanoes, although the activity is still prolonged after the period of elevation.

As regards the geological importance of volcanic and earthquake phenomena, their significance is but local and accidental. Volcanoes and earthquakes are and always have been confined to limited areas of the earth's surface, and the products of volcanic action make up but a small portion of the solid crust of the globe. Great mountains and mountain chains are not volcanic either in their nature or their origin, though sometimes crowned by volcanic cones; nor are earthquakes and volcanoes to be looked upon as anything more than incidental attendants upon the great agencies which are slowly but constantly raising and depressing continents.

ON THE ELECTRICAL CURRENTS OF THE EARTH.

By Carlo Matteucci.

[*Translated for the Smithsonian Institution, from the "Memoirs* of the Italian Society of Sciences founded by Anton Mario Lorgna."*]

The object of this memoir is to describe a long series of experiments, commenced in 1863 and only interrupted by brief intervals, on the phenomena called *electric currents of the earth*, meaning by those words the electric currents which circulate in a mixed circuit formed of a metallic line and of a terrestrial stratum, and which do not depend on causes known and existing either in the metallic part of the circuit or in its extremities communicating with the ground. The conclusions arrived at in this inquiry do not comprise, to any great extent, an explanation of these currents founded on a known physical theory, or the thorough knowledge of the laws of the phenomena. We trust, however, that the results obtained are of sufficient importance and exactness to recompense the long and persevering efforts which were necessary to obtain them. We hope also to be pardoned by any one who shall undertake seriously to study this subject, if we have not carried these researches to such a point as might be desired, since it must appear evident from the experiments made that the means requisite to extend and complete them exceed the resources of a private individual.

HISTORICAL PART.

Even from the time when the galvanometer was discovered—that is to say, shortly after the celebrated experiments of Oersted and Ampère—phenomena of electrical currents are cited as having been obtained by introducing the extremities of the instrument into different points of a terrestrial stratum.

We believe that Fox was the first who observed the deviation of the needle of the galvanometer, on inserting the copper points attached to the ends of the wire of this instrument in various places of a mineral vein of copper. Becquerel, soon after Fox, published a long series of experiments on the electric currents, which he obtained by sinking the electrodes of the galvanometer in earth taken in different conditions of humidity and of composition.

It is scarcely necessary to say that all these experiments were but different cases of the general principle of the galvanic pile; that is to say, of heterogeneity in the metallic laminæ in contact with the ground and the liquids with which the ground was imbued at the points in contact with the electrodes. It would be easy, even supposing the employment of homogeneous electrodes, by which electric currents are not produced through their immersion in water, to exhibit distinct signs of electric currents by using liquids of different chemical composition or of different temperature in contact with the electrodes. This would be

* *Serie terza: Tomo* I, *Parte* I.—Firenze, 1867.

a manner of repeating, by using the earth as an intermediate conductor, the experiments tried, especially by Nobili, many years ago, on the reciprocal chemical actions of different liquids. The same may be said of electric currents obtained with electrodes in which may be formed the so-called secondary polarizations.

These different modes of obtaining electric currents in a mixed circuit have nothing to do with the study in which we are engaged, if not on account of the very important and indeed indispensable knowledge of the causes of error which are apt to intrude into the experiments by which we seek to discover and to study the electric currents of the earth, independently of those causes.

I believe that the first case of electric currents proper of the earth, which may be called, as has been done by Airy, *spontaneous terrestrial electric currents*—at any rate, if not the first observed, certainly the first described and published—was that which was discovered on the night of the 17th of November, 1847, at Pisa, by means of the telegraphic wires, and which was described in a letter directed to Arago and published in the *Comptes-rendus* of the Academy of Sciences of Paris. This fact consisted in the existence of an extraordinary electric current which circulated with such intensity and constancy as to keep the armatures of the electro-magnets of the apparatus in a state of attraction during the whole time that a magnificent aurora borealis was apparent in the heavens. The same phenomenon was soon afterwards observed in the United States, and since that epoch the observations have been frequent of electric currents in the wires of the telegraph associated with the appearance of the aurora. When it is considered that we know, on the other hand, the constant relation which exists between the aurora borealis and the indications shown by the instruments which serve to measure the magnetic force of the earth, it is impossible not to recognize all the importance of these studies. And in fact, after these observations, there was no delay in directing special researches to the existence of electric currents of the earth and their laws, independently of the apparitions of the aurora borealis.

We must be content, on the present occasion, with briefly referring to the researches made previously to our own, and which are due to Baumgarten, Barlow, Lloyd, and Walker, but especially to Lamont, who, beyond the rest, has extended and varied these investigations. Whoever has studied the memoirs of these observers with the attention due to the importance of the subject, and to the authority of their authors, will find it difficult to avoid the conclusion that the uncertain results obtained, results so little accordant among themselves, are principally attributable to the method of experimenting and to the disturbing causes necessarily introduced by that method. The greater part of the experiments were executed with telegraphic circuits, and therefore with a metallic line established in conjunction with other metallic lines worked for the purpose of correspondence, and traversed by the electric currents of the offices at the moment of the experiment. We know that the wires of telegraphic lines are never so perfectly insulated from one another and from the earth that there shall not be signs of the current in the lateral wires when the circuit is closed with one of the same wires. Moreover, the communications of the metallic lines with the earth are now made with a lamina of copper immersed in pits, the wires being at one time connected with the iron tubes of pumps, at another with iron railways. In the memoirs which we have referred to there is generally no indication of the mode in which the lines were constructed, nor as regards their insulation or their connection with the

earth. Nor in most cases are we informed whether or not the numbers reported were obtained by experiments made, as is quite probable, at the time when the lines were in service for telegraphic correspondence.

It would be useless, we think, to enlarge critically upon the experiments to which we allude or the results obtained. To such criticism a distinguished Swiss physicist, M. Dufour, of Lausanne, has lately devoted himself, and we content ourselves with citing, in his own words, the conclusion to which he has arrived: "It is quite evident that if researches are to be undertaken respecting the electric currents of the earth, offering any solid guarantee of exactness, it is necessary to employ special lines and such as are absolutely independent of the telegraphic reticulation."

Among our predecessors in these researches, Lamont alone seems to have bestowed some previous attention on the method of experimenting and on the causes of error incident to the methods followed. Hence the eminent astronomer of Monaco confesses that he had not yet found in these experiments *a point of departure sufficiently secure*, and closes his memoir with the admission that what he had published up to that time *ought to be regarded only as a few general and preliminary indications.* In a word, I do not think it an exaggeration to affirm that it would be impossible, from all the researches which I have cited, to draw the demonstration of the existence of the phenomenon of an electric current which circulates in a metallic line extended along the earth, and insulated from it, having its extremities sunk in the ground, independently of the heterogeneity of the electrodes and of the various causes of error introduced into those experiments; meaning by that phrase causes already known, and which have nothing to do with a proper electric stratum of the earth.

METHOD OF EXPERIMENTING.

The description of this method should embrace the metallic part of the mixed circuit, the communications between the extremities of the metallic line and the ground, and the instruments used to detect and measure the current.

Metallic line.—I will state, in the first place, that none of the experiments described in this memoir have been executed upon a wire pertaining to a telegraphic line composed of several other wires. Whenever I have used a telegraphic line, it has consisted of a single wire; and the experiments were made either during months when the telegraphic service was not conducted by that wire, or at hours when that service was known with certainty to be suspended. Before commencing the experiment the line was examined throughout its course, and protected by the removal of any possible contact with the boughs of trees or the walls of houses, and by the renewal of the solderings of the junctions. The line was formed of the usual iron wire of telegraphic connections, 3 or 4 millimetres ($\frac{1}{8}$ of an inch) in diameter. Its extremities were united to the instruments, and the electrodes sunk in the ground by means of a piece of copper wire covered with gutta-percha, freshly soldered outside of the telegraphic offices, and all communication was interrupted between the line and the usual wires entering the offices. The insulation of the line was always tested before commencing the experiment, and was always such as not to impart during dry days a sensible deviation to a galvanometer of 2,000 coils.

In many of the experiments which we shall report, a copper wire, 2 millimetres ($\frac{1}{12}$ of an inch) in diameter and covered with gutta-percha,

was used; which wire was in some cases stretched upon the ground, in others sunk at a slight depth beneath the surface of the earth, but oftenest suspended on slender rods of wood, like those employed for field-telegraphs.

Electrodes.—This is naturally the part of a mixed circuit requiring the greatest attention, and I have been able to avoid causes of error in this respect from the assurance, which I had obtained in the experiments of electro-physiology, that electrodes of amalgamated zinc, immersed in a saturated and neutral solution of sulphate of zinc, do not excite between them an electric current, and do not acquire secondary polarities by the passage of a voltaic current.

The electrodes which I have employed are rectangular plates of laminated zinc, from 6 to 8 centimetres (2½ to 3 inches) in width, and from 12 to 16 (5 to 6 inches) in height, perfectly amalgamated and joined to the metallic line by means of a circuit-breaker with two holes, into one of which enters the wire and into the other the extremity of a projection on the plate of zinc. This plate is immersed in a saturated and neutral solution of sulphate of zinc, contained in a porcelain cylinder like that of Grove's battery. In the selection of these cylinders care must be taken to reject those which are so porous as to admit too readily of the percolation of the liquid.

The porcelain cylinder thus prepared is immersed in well or spring water, which should be the same at both extremities. For the reception of the water in which the cylinders are sunk, I have used different contrivances. Sometimes, after having formed in the ground a sort of pit, varying in depth from a half metre to two metres, I have made in the bottom of this pit a cavity, shaped like a capsule, from 10 to 12 centimetres (4 to 5 inches) wide, and of such a depth that the porcelain cylinder, when introduced, should reach with its rim the level of the bottom of the pit. Then, in order that the water poured into this kind of capsule may not be too speedily absorbed by the ground, I line the capsule with a stratum of tempered potter's earth, such as is used in earthenware manufactures. At other times I have used flower-pots, which are sunk in the ground, the earth being compressed around the vessel. In some cases, finally, the porcelain cylinder was inserted and fixed in a large piece of cork, so that the cylinder might remain floating on the water of a well, but almost entirely immersed therein; the copper wire covered with gutta-percha, which is joined to the plate of zinc, is wound around a small cord, by means of which the floating body is made to descend in the well.

I have made many experiments to assure myself of the homogeneity of the electrodes thus prepared. It is very easy to obtain this homogeneity and to preserve it with porous cylinders. We begin by having a certain number of such cylinders, quite new, and by filling them to the same height with a solution of sulphate of zinc; we select those which do not readily imbibe the liquid or allow it to escape, and immerse simultaneously two of those thus selected, after they have been well dried with a clean towel, in a vessel filled with the same water. In this way, even with a galvanometer of 20,000 coils, we promptly find the two electrodes perfectly homogeneous. It happens, however, not unfrequently, that, if the cylinders are left in the water for some time or withdrawn and again immersed, a certain current will be observed to arise between them. If the cause of the difference which has thus originated be attributable to the plates of zinc, which is the rarer case, it is necessary to reamalgamate them; if, on the other hand, the heterogeneity be due to the porcelain cylinders, we must withdraw these from the water, dry

them repeatedly with a cloth, and renew the water in which they are immersed. To procure homogeneous vases of terra-cotta for containing the water in which the porous cylinders are to be immersed is more difficult, and in order to succeed we must leave them to imbibe water for several days, and then prove them; but even then there are scarcely to be found, among many, two between which signs of heterogeneity do not present themselves.

In some experiments I have been accustomed to excavate a hole of moderate dimensions at the two extremities of the circuit, and to fill each hole with the same earth, into which the terra-cotta vase was then introduced. Most frequently I have satisfied myself, before commencing the experiment, that there was no current between the electrodes, by sinking the two vases in two holes of moderate size made in contiguity with one another. I have also, whenever it was practicable, reversed the position of the two earthen vases and noted the difference, if there were any, of the deviations obtained in the two cases, in order to discover whether the heterogeneity of the vases was noticeable, and to what extent in the current detected.

I have sought finally to ascertain whether, in any case, it would be possible to substitute for the electrodes which I have described two plates of copper sunk in the ground, which would be much more simple and convenient; and I have found that, whatever might be the state of these plates before submitting them to experiment, that is to say before using them, either in a different condition of purity or oxidation as they most frequently occur, there was always realized, from the first, with the galvanometer of 2,000 coils, a very strong deviation, of which it was impossible to foresee the direction. It constantly occurred, however, that, on keeping the circuit closed and leaving the plates of copper buried and undisturbed in the earth, this deviation slowly diminished, and after eighteen or twenty hours became comparatively insignificant. At this juncture, it was only necessary to stir slightly one of the plates, or to press the contiguous earth, or to throw a little water on the spot where the two plates were sunk, in order to excite a deviation, which would afterwards very gradually disappear. It was also found that on withdrawing the plates from the ground, when the deviation had ceased, the latter reappeared, if the plates were replaced in the earth either at the same or at any other point. It is scarcely necessary to say that when a current was made to pass, with electrodes of copper, across the mixed circuit, the effects of secondary polarity were realized.

In conclusion: there would be no security in the results if, in these experiments on the electric current of the earth, electrodes of copper were used without the proper precaution; but by employing those electrodes only after they have been left buried for twenty-four hours in the earth and with a closed circuit, the proper currents of the earth are obtained with the same deviation and the same constancy as with electrodes of zinc, and even with greater intensity; and this probably through the greater extension and depth of the electrodes of copper in comparison with those of zinc.

Galvanometer.—Unfortunately I have not been able always to use, in these protracted experiments, the same galvanometer; nevertheless, in two of the most important series I have constantly used a galvanometer of 2,000 coils, with a distinctly astatic system, and which underwent no variation in the whole series of experiments.

When I have wished to ascertain the electric state of the atmosphere, I have used a thin wooden rod, 6 or 7 metres, (20 or 23 feet) in height. At the upper extremity of this rod a porcelain insulator was

fixed, which bore a small arm of iron with a diminutive pulley. By means of a silk thread and of the pulley, I elevated a copper wire covered with gutta-percha, which, at the upper extremity, was terminated by a large uncovered portion coiled spirally, into which I introduced a sort of cornet, formed of divers layers of touch-wood, and kindled it at the moment of the experiment. The lower extremity of this copper wire was united to the ball of an electroscope attached to a dry galvanic pile.

EXPERIMENTS WITH A MIXED CIRCUIT OF A LENGTH NOT GREATER THAN A KILOMETRE* IN A HORIZONTAL STRATUM.

Experiments under these conditions have been often tried, by placing the electrodes of zinc sometimes in contact; sometimes at distances varying from 10 to 20, 50, and 100 metres. It is, in fact, by these experiments which I am accustomed to make previously to undertaking those with much longer circuits, that I satisfy myself that there is no heterogeneity between the electrodes of zinc formed in the manner above described. I have been thus enabled many times to ascertain that if on such an occasion there was a slight deviation it depended on the vases of terra-cotta, and that there was no regularity in the currents thus obtained on transporting the vases to different distances within the above limits. In fact, the current is sometimes found to increase on a wider separation of the vases than to diminish or even disappear, and sometimes to an inverse order on the removal of the vases to still greater distances. In these cases I have always succeeded in recognizing that there was a difference in the physical qualities of the ground. Thus a current arises if one electrode be placed in a soil charged with loam, and the other in an argillaceous soil; and in operating on the sands adjacent to the sea, a current supervenes if the electrodes be stationed at different distances from the beach. But the effects of these differences of soil are only manifested when in contact with the vases containing the electrodes. Hence, if it be found that a current exists between two points at a distance of 15 or 20 metres (49 or 66 feet) from one another, we may be sure of causing it to cease by excavating at those points two holes, which need not have a diameter of more than one metre, (3 feet,) and filling them with the same earth, into which the vases with the electrodes are then to be introduced. It is advisable, therefore, to pursue this course when operating with mixed circuits at great distances, provided it be not previously ascertained, as I have always attempted to do when practicable, that the deviation remains invariable on reversing the position of the electrodes and their vases. In order to remove all doubt as to whether the earth in which the electrodes were sunk might not influence the results found when the circuits were very long, I have been accustomed to make, at each of the extreme stations, four or five holes at a distance of 10 or 20 metres (33 or 66 feet) one from another, and to proceed forthwith to the proof of homogeneity by changing the position of the vases.

I pass now to a description of the experiments made on such mixed circuits as are much longer than those just described, on circuits, namely, having the full length of a kilometre, (3,281 feet.) With a view to experiments of this kind, I selected a large, horizontal meadow, adjacent to the Arno, and forming part of the Cascine of Florence. The earth of this meadow, at least to the depth of the 25 or 30 centimetres (10 or 12 inches) requisite for imbedding the vases of the electrodes, possessed

* Kilometre = 1093.6389 yards.

apparently the same physical qualities, being, in fact, an arenaceous formation, as is commonly the case in the neighborhood of rivers. The electrodes of zinc were placed successively at the distance of half a metre, (20 inches,) then of 11 metres, (36 feet,) then of 148, (328 feet,) then of 750, (2,461 feet,) then of 1,060, (3,477 feet.) At each of these stations I excavated four or five holes, in order to vary in every instance the position of the electrodes. The experiments were made by successively advancing and then returning to the same holes; by stretching the skein (*metassa*) of copper wire covered with gutta-percha, in conjunction with its head, (?) to one of the electrodes, and then recovering the skein and turning back again. The copper wire covered with gutta-percha was at one time stretched upon the ground, at another suspended upon poles, at another buried in the grass. It is superfluous to add that, in making these experiments, all the precautions above described were employed, in order to obtain and preserve the homogeneity of the electrodes.

The result obtained from these experiments, many times repeated, with every precaution to secure exactness, was that *in a mixed circuit, formed of a metallic line and a stratum of earth, horizontal, or as nearly so as possible, of a length not greater than a kilometre,* (3,281 *feet,*) *under a clear sky, and with the air calm, there is no proper current of the earth discoverable with a galvanometer of* 2,000 *coils.* Yet, in a circuit of this length, I have noticed, on days of storm and atmospheric disturbance, sudden deviations under the action of the electric discharges.

EXPERIMENTS WITH A MIXED CIRCUIT, OF THE LENGTH OF SIX KILOMETRES, IN A STRATUM NEARLY HORIZONTAL.

With the aid of the corps of engineers, I was enabled to establish on the great plain of San Maurizio, distant 22 kilometres (13½ miles) from Turin, a plain set apart for military maneuvers, two mixed circuits, each of which consisted of a stratum of earth and of a copper wire, 2 millimetres ($\frac{1}{12}$ of an inch) in diameter, and covered with gutta-percha. One of these wires was stretched in the direction of the magnetic meridian, the other in a plane perpendicular to that meridian. Both wires had about the same length, namely, 6,400 metres, (4 miles.) The copper wire was suspended upon small wooden poles, such as are used in field constructions of telegraphic lines. At the extremities of the two lines a hole was excavated, of a rectangular form, with a depth and length of 2 metres, (7 feet,) and a width of 1 metre, (3 feet;) in the bottom of this hole a cavity, or capsule, such as has been above described, was constructed, having a width and depth of 30 centimetres, (1 foot,) and lined with clay, so as to allow no filtration of water. The four cavities were then filled with the same water, which was that of a copious waste-pipe of one of the canals which traverse the plain; in this water the porcelain cylinders, with the electrodes of zinc, were immersed.

The first experiments were directed to a verification of the equal conductibility of the two mixed lines. It should be premised that the two metallic lines, north–south and east–west, were interrupted about midway, and entered at that point into a small chamber, where I had stationed the galvanometers. In the greater number of the experiments I used a galvanometer of 1,500 coils, with an astatic system; unluckily, this instrument sustained some injuries in being transported, when the experiments were finished, to Turin, so as to be no longer capable of being operated with.

To measure the conductibility of the two mixed circuits, I caused the current of a good Daniell's battery to pass, first in one, and then in the

other, and determined with a rheostat the conductibility of the two circuits. The difference between the two was, from the first, very small, and it was only necessary to excavate by a centimetre, ($\frac{4}{10}$ of an inch,) or thereabouts, the two holes of the line which had the greater resistance, in order to render both of equal and constant resistance. Proof of homogeneity was also made by filling two large holes, which had been excavated in close contiguity, with the same earth procured in forming the holes at the extremities of the lines. In the holes thus filled I formed the two capsules already described, and introduced therein the usual electrodes; when these were in operation, having been first well prepared, no current was found on the introduction of the electrodes into the holes.

After these preliminary arrangements I commenced a series of observations which were continued about a month, from the 12th of March to the 15th of April, 1864, being the season generally of clear skies and of cool and dry air; there were two or three days of a strong easterly wind and one of storm with rain. For the space of ten days the observations were never interrupted night or day, and two soldiers who relieved one another were stationed as a guard at each hole. The galvanometer used was one of 1,500 coils and gave a fixed deviation of 60°, with a Daniell's battery introduced into one of the mixed circuits.

The following were the results obtained from the long series of observations made in the manner and at the time indicated:

1. In mixed circuits, formed of a copper wire, and a stratum of earth very nearly horizontal and about 6 kilometres (4 miles) long, there is always an electric current which circulates with intensity and in determinate directions according to the direction of those circuits in regard to the magnetic meridian; this current cannot be absolutely attributed to the heterogeneity of the electrodes, or of the terrestrial strata in contact with those electrodes.

2. These currents have an intensity which increases in proportion to the depth at which the electrodes are sunk beneath the surface of the earth, from 50 centimetres (20 inches) to 2 metres (7 feet.) This greater conductibility possessed by the mixed lines in proportion to the depth to which the electrodes are sunk, explains the variation discovered in the intensity of the electric currents of the earth under these circumstances. This result is in conformity with that which is observed after rain, and which is due to the greater humidity of the ground in contact with the electrodes.

3. When the cavities in which the electrodes are sunk have a depth of 2 metres (7 feet) or more, or when the electrodes are immersed in the water of wells, the extension of the laminæ of zinc and the diameter of the porous vases have little influence on the intensity of the terrestrial currents.

4. In the circuit extended along the magnetic meridian or south-north, the electric current had always a constant direction and an intensity which varied very feebly while manifesting a certain period. For a month, several hundreds of varied observations showed that the terrestrial current was always directed in the metallic part of the circuit from south to north, and that the needle of the galvanometer never became fixed at zero nor in the opposite quadrant, and that its oscillations were always small and very slow.

5. On comparing with one another the slightly unequal deviations obtained in nine entire days of constant observation, it results that the current in the south-north circuit presents in twenty-four hours two *maxima* and two *minima* of intensity. The two *minima* occur, one in

the day, and the other in the night, at very nearly the same hours, namely from 11 to 1 o'clock. After 1 o'clock at night the current increases, and from 5 to 7 o'clock in the morning a *maximum* is noticed; in the day this *maximum* oscillates between 3 and 7 o'clock in the afternoon. The differences between the *minimum* and *maximum* of intensity are a litte greater than that between 1 and 2.

6. In the circuit perpendicular to the magnetic meridian the results are very different and subject to great variations. It frequently occurs that the needle is seen to remain at zero, or oscillates to one side or the other of that point, moving from 2° to 3° and even to 14° and 15° on the same side. The direction of the current most frequently observed in this circuit was from west to east in the metallic part. In general the needle is never fixed and sometimes executes very wide and rapid oscillations.

7. It was never noticed that the differences of temperature, which fluctuated between zero (32° F.) and + 18° (65° F.) and + 20° C. (68° F.), the varying humidity of the air, or even rain, had any influence on the direction of the current existing in the circuit extended along the magnetic meridian.

8. These results were not varied on changing the position of the metallic portion of the circuit—that is, on using the metallic line extended on the ground or suspended on poles.

EXPERIMENTS ON MIXED CIRCUITS OF A LENGTH VARYING FROM 200 METRES TO MANY KILOMETRES, THE ELECTRODES BEING SUNK IN THE GROUND AT A GREATER OR LESS DIFFERENCE OF ELEVATION.

The first experiments of this kind were made on the hill of the Villa della Regina, near Turin. The mixed circuit established there was composed of an iron wire insulated in the usual manner, and about 600 metres (1,969 feet) long in a straight line, with a direction intermediate between S. E. and N. W.: the two extremities of this wire were united to the usual electrodes of zinc sunk in the ground at a difference of level of 150 metres (492 feet.) In these experiments also the pits in which the electrodes were sunk had been filled with the same earth, and the capsules or cavities already described were then formed and lined with clay. In some of the experiments, the porcelain cylinders and the zinc electrodes were suspended in the water of two wells in the manner before stated.

The experiments have been continued month after month, at different seasons of the year, and not rarely the needle of the galvanometer has been observed for entire days at very short intervals of time. *I have constantly found in the circuit in question an ascending current in the metallic line*, of an intensity which in clear and calm days was constant or manifested very inconsiderable oscillations.

The position of the electrodes was frequently changed, by placing lowermost that which was highest, and *vice-versa*, yet the current never varied in direction, and very slightly in intensity. For a certain time the galvanometer used in these experiments was that of 1,500 coils, which had served me on the plains of San Maurizio, in the experiments with the circuits of 6 kilometres, (4 miles,) and the intensity of the current was always found to be much greater than that realized in the circuit of 6 kilometres. The ascending hill-current was, with this galvanometer from 20° to 25°, while that realized in the circuit of 6 kilometres, and where consequently the resistance was much greater, never exceeded from 5 to 6 degrees in the line of the magnetic meridian. The intensity

of the ascending current was not altered by the substitution of the copper wire covered with gutta-percha for the insulated iron wire, nor were any differences noticed when the wire was extended on the ground covered with grass or with snow.

I have seen the intensity of the current increased by placing the electrodes in the ground at a depth of 10 centimetres (4 inches) below the bottom of a pit from 1 to 2 metres (3 to 7 feet) deep; and while in excavations of inconsiderable depth, the ascending current has marked from 15° to 16°, in those much deeper, and in wells, it has indicated more than 20°. When the electrodes are in a very superficial stratum the deviation is less fixed than when they float in the water of wells. In the latter case the deviation remains constant from hour to hour, if the day is clear and calm, nor is it changed by reversing the position of the electrodes in the wells.

It may, I think, be of use to cite here a series of numbers which exhibit the deviations realized on certain days of July, 1864, with electrodes sunk in excavations having a depth of 2 metres (7 feet.) The atmospheric electricity was of moderate intensity and constantly positive; the sky in part clear, and in part overcast. The galvanometer with which I operated was one of 2,000 coils.

Day.	Hour.	Deviation produced by the ascending terrestrial current in the metallic line.	State of the sky.	Day.	Hour.	Deviation produced by the ascending terrestrial current in the metallic line.	State of the sky.
		Degrees.				*Degrees.*	
July 15	7 a. m.	23......	Electricity + abundant; sky clear, and 27° C., (80° F.)	July 16	12.20 p. m.	25	
	7.30 a. m.	23 to 26			1 p. m.	25	
	7.45 a. m.	23 to 26			2.30 p. m.	23	
	8 a. m.	23 to 24			3 p. m.	19	
	8.12 a. m.	22 to 23			4.30 p. m.	30	
	8.18 a. m.	23			5 p. m.	28	
	8.20 a. m.	24			5.30 p. m.	27	
	8.30 a. m.	23 to 24			6 p. m.	28	
	9 a. m.	23 to 24	Electricity positive minimum.		7 p. m.	27	
	9.20 a. m.	23 to 25			7.30 p. m.	28	
	10 a. m.	25			8 p. m.	28	
	10.30 a. m.	22......	Clouds sparse and + 27° C.		8.30 p. m.	28	
	11 a. m.	24			9 p. m.	27....	Storm.
	11.30 a. m.	24			9.30 p. m.	28	
	12 m.	23			10.30 p. m.	27	
	12.30 p. m.	25		July 17	5.30 a. m.	29....	Fair and calm after the storm of the night.
	1 p. m.	24 to 25			8 a. m.	30	
	1.30 p. m.	23 to 24			9 a. m.	34	
	2 p. m.	24			9.15 a. m.	35	
	2.30 p. m.	27			9.35 a. m.	35	
	3 p. m.	24			10 a. m.	35	
	3.18 p. m	23 to 24			10.30 a. m.	34	
	3.30 p. m.	28			10.50 a. m.	33	
	4 p. m.	16			11 a. m.	33	
	4.30 p. m.	17			11.10 a. m.	34	
	5 p. m.	18			11.30 a. m.	33	
	6 p. m.	18			11.40 a. m.	33	
	6.30 p. m.	19			12 m.	31	
	7 p. m.	20			12.20 p. m.	31	
	7.30 p. m.	21 to 22			12.30 p. m.	31	
	8 p. m.	22			1.30 p. m.	29	
	8.30 p. m.	24			2 p. m.	28	
	9 p. m.	20			2.30 p. m.	26	
	9.30 p. m.	22			3.30 p. m.	25	
	10 p. m.	24			4.10 p. m.	24	
	10.30 p. m.	25			4.35 p. m.	28	
	11 p. m.	25			4.40 p. m.	28	
July 16	4 a. m.	25			5.25 p. m.	27	
	7 a. m.	23 to 24			6.30 p. m.	28	
	9.30 a. m.	25			7 p. m.	25	
	10 a. m.	24			7.15 p. m.	25	
	11 a. m.	25					

It is impossible to discover in the numbers here reported any relation between the intensity of the terrestrial current and the hour of the day. The augmentation observed at the close of the 16th day, and in the morning of the 17th, was probably owing to the rain which fell in that interval, and in fact this result never fails to be obtained when we sprinkle two or three buckets of water around the electrodes. In the first hours of each of the days cited, I assured myself of the homogeneity of the electrodes by immersing them simultaneously in the water and from time to time reversing their position. The most important precaution is that of frequently ascertaining that the water maintains a constant level in the cavities in which are immersed the porcelain cylinders of the electrodes.

I further report the numbers obtained in one of the observations which I conducted with the electrodes suspended in two wells, one at the top, the other at the base of the hill before mentioned. These numbers were obtained with the galvanometer of 1,500 coils. In this experiment the position of the electrodes was twice inverted.

Day.	Hour.	Deviation produced by the ascending current in the metallic line.	State of the sky.	Day.	Hour.	Deviation produced by the ascending current in the metallic line.	State of the sky.
		Degrees.				*Degrees.*	
July 25	12.15 a. m.	32....	Clear.	July 25	2 p. m.	40	
	2.24 a. m.	32			2.30 p. m.	42	
	5.30 a. m.	40			3 p. m.	40	
	5.50 a. m.	42			4 p. m.	40	
	6.20 a. m.	42			5 p. m.	40	
	7.45 a. m.	40			8.30 p. m.	40	
	8.30 a. m.	40			9 p. m.	40	
	10 a. m.	42			9.30 p. m.	40	
	11 a. m.	40			10 p. m.	40	
	12 m.	40			10.30 p. m.	41	
	12.30 p. m.	40		July 26	12.30 a. m.	41	

It is evident from the above that the deviation produced by the use of electrodes floating in the water of wells is more constant than that resulting from their employment when sunk, as we have described, in the earth, for in the latter case the water in which the cylinders are immersed is continually decreasing. I ought here to observe that, having taken advantage of a well, situated midway on the slope of the hill of Turin, I repeated these experiments with the same length as before of the metallic line, and in one case with a stratum of earth extending from the base to about the middle of the hill, and in the other case from the middle to the top, the electrodes being all the time immersed in wells; in the experiments in which the terrestrial circuit was thus about half that before used, the fixed deviation of the ascending current was 10°; much less therefore than that obtained between the base and summit of the hill.

I deem it proper further to describe the principal results derived from an uninterrupted series of experiments made through all the months of last summer, in the hills around Florence. The line was composed of the usual copper wire covered with gutta-percha, suspended upon poles and interrupted about midway of its entrance into the laboratory, where the two ends were immersed simultaneously with the wires of the galvanometer of 1,500 coils, in two small vases filled with quicksilver. In

many experiments I have used another but similar line, which enabled me to test, by comparison with one another, the two electrodes immersed in close contiguity, now in the lower station, now in the upper. The electrodes were the usual plates of amalgamated zinc, immersed in the solution of sulphate of zinc contained in porcelain cylinders, which cylinders were immersed in turn in well or spring water contained in two vases of terra-cotta, buried in the earth. It is useless to state that these electrodes were first tested, and that every precaution was used to ascertain their homogeneity. At the two extremities, after selecting a soil having very nearly the same qualities, I excavated two holes, with a width and depth of one metre, (3 feet,) which I filled with the same earth, and into the holes thus prepared introduced the vases with the two electrodes. On each day of experimenting, I began and finished by reversing the position of the vases, in order to assure myself that the deviations were independent of the electrodes, and that, when tested in contact, the latter were perceptibly homogeneous. The difference of level between the two electrodes was about 55 metres, (180 feet.)

Simultaneously with the observations of the electric currents in the circuit, I studied at the extreme stations the atmospheric electricity in the way already described. On clear and calm days I have always found very strong signs of positive electricity near the upper station, and no signs or very weak ones of the same electricity in the valley below, near the lower station; indeed, at this station the same thing occurred even in stormy weather. At the upper station the signs changed according to the intensity and distance of the existing storm, as we shall again mention. I select the numbers obtained on the 2d, 3d, and 4th days of July, when the air was warm and dry, and the weather calm with the exception of a distant storm which was observed on the 3d, some hours after midday. On the 2d, from morning until 10 at night, the current continued to ascend in the metallic line, and remained fixed at between 15° and 16° during the morning, and between 11° and 12° in the afternoon. The results of the 3d were the following:

Hour.	Deviation.	Hour.	Deviation.	Hour.	Deviation.	Hour.	Deviation.
	Degrees.		*Degrees.*		*Degrees.*		*Degrees.*
8 a. m..	13 to 14	2.32 p. m...	18	3.12 p. m...	15	4.40 p. m..	17
9.42 a. m..	15	2.40 p. m...	18	3.43 p. m...	18	5.40 p. m..	18
12 m....	8	2.45 p. m...	18	3.50 p. m ..	18	8.50 p. m..	14
1.16 p. m..	12	2.48 p. m...	15	4.5 p. m...	15	9.30 p. m..	30
1.30 p. m..	12 to 13	3 p. m...	18	4.20 p. m...	18	10.15 p. m..	15

The electrodes having been left in place all night, the current was found the next morning, fixed at between 14° and 15°, and the same deviation remained on reversing the position of the electrodes.

I report also the numbers obtained May 30, on which day a peculiar storm occurred, a strong sirocco wind having prevailed, while for some time the sky was covered with dense clouds traversed by electric discharges in the distance. Rain also fell.

Hour.	Deviation of the usual ascending current in the metallic line.	State of the sky.	Hour.	Deviation of the usual ascending current in the metallic line.	State of the sky.
	Degrees.			*Degrees.*	
7 a. m.	22......	Rain for some time.	2.10 p. m.	(*)	
8 a. m.	18 to 20		2.15 p. m.	(*)	
9.14 a. m.	23		2.30 p. m.	(*)	
12 m.	20......	Strong wind.	2.36 p. m.	(*)	
12.20 p. m.	21		2.40 p. m.	10......	Heavy rain, which lasts until 4 p. m., with thunder and lightning, and dense black clouds on the line.
12.30 p. m.	20		2.50 p. m.	10	
12.37 p. m.	18		2.53 p. m.	15	
12.45 p. m.	20		3 p. m.	20	
1 p. m.	20		3.10 p. m.	20	
1.15 p. m.	15		3.15 p. m.	20	
1.20 p. m.	10		3.18 p. m.	22	
1.30 p. m.	8		3.29 p. m.	25	
1.40 p. m.	5		3.25 p. m.	23	
1.45 p. m.	(*)....	Stormy clouds, very low and menacing, flashes of lightning, thunder and rain.	3.30 p. m.	20	
1.50 p. m.	(*)		3.35 p. m.	25	
2.5 p. m.	(*)		3.38 p. m.	25	
2.8 p. m.	(*)				

(*) Needle oscillates between 5° and 0°.

Up to this moment the needle oscillated slightly; but afterwards, under the action of the storm, the needle made great oscillations, though always to the side in which the current maintains it, and at the close of the day the deviation seemed fixed at about 60°. It has already been said, that on July 2, with a clear sky and the air warm and dry, the deviation was re-established and fixed at between 15° and 16°.

During a storm on the 7th I kept the electroscope in exercise for a length of time at the intermediate station, and constantly realized great oscillations of the needle, even to zero, when the instrument gave signs of negative electricity or very weak signs of positive electricity. Under strong winds also these oscillations were verified. Again, the usual deviation of the ascending current increased slowly or rapidly, according as the electroscope indicated a corresponding augmentation in the signs of positive electricity, or a sudden augmentation of the same electricity at the moment of a flash of lightning. In many other series of experiments, which I deem it needless to report, I have always found in calm and clear days a deviation nearly constant, a result which I have never witnessed during storms nor even on clear days during high winds and great oscillations of the atmospheric pressure.

I proceed to describe the experiments executed upon a mixed circuit in which the metallic conductor, an iron wire of 3 millimetres, (⅛ inch,) and well insulated, had a length of about 45 kilometres, (28 miles.) The two extreme stations, which were Pontedera and Volterra, were at a difference of elevation amounting to 540 metres, (1,772 feet.) The experiments were performed in the nights of the 11th and 23d of July, under a calm and serene sky, commencing at 7.30 p. m. and terminating at 4.45 a. m.

In the line between Pontedera and Volterra the telegraphic offices are closed at night; and in order to be more certain that no current of the telegraph could be introduced during the experiments on the line, I provided for an interruption of the latter at each extremity, at the distance of a pole or two from the office; at the point of interruption I soldered a piece of copper wire covered with gutta-percha, which at the station of Volterra descended immediately into the earth, where it was united to

the electrode of zinc sunk in the ground in the usual manner, while at the station of Pontedera, where the galvanometer was placed, the above-mentioned wire proceeded to one of the ends of the galvanometer, while the other end was made to communicate with a copper wire covered with gutta-percha which terminated at the earth and united with the other electrode of zinc.

The following are the numbers obtained from the two experiments, in both of which the constant deviation of the needle indicated the usual ascending current in the wire:

July 17.				July 23.			
Hour.	Deviation.	Hour.	Deviation.	Hour.	Deviation.	Hour.	Deviation.
7.30 p. m..	17	11.30 p. m..	10	8 p. m...	6	10 p. m..	20
8 p. m..	11	1 a. m..	15	8.15 p. m...	20	10.15 p. m..	10
8.30 p. m..	13	1.30 a. m..	15	8.30 p. m...	30 to 40	12.30 a. m..	25
9 p. m..	10	2 a. m..	14	8.45 p. m...	28	2.35 a. m..	40
9.30 p. m..	12	2.30 a. m..	15	9 p. m...	28	3 a. m..	36
10.15 p. m..	10	3 a. m..	18	9.20 p. m...	10	3.55 a. m..	38
10.30 p. m..	12	4 a. m..	21	9.25 p. m...	20		
11 p. m..	10	4.30 a. m..	8	9.30 p. m...	22		
11.15 p. m..	16	4.45 a. m..	10	9.45 p. m...	30		

In these experiments, especially in that of the night of the 11th of July, the deviation had been constant in the interval between one observation and another, and the variations took place very slowly. But this constancy was not so absolute as that noticed in the previous experiments with a short circuit; the needle in these experiments between Volterra and Pontedera having constantly exhibited a sort of tremulous oscillation in an arc, which was never greater than one degree. Moreover, as well in the experiments of the 11th as in those of the 23d of July, it was observed that, thrice on the former and four times on the latter night, at various intervals of time, the deflected needle, which had seemed fixed, suddenly descended to 0° and oscillated, oftenest for a few seconds, but on one occasion for about an hour in the opposite quadrant, never taking a fixed direction, and returning by a rapid movement to its stationary position under the ascending current. These extraordinary movements of the needle, I am persuaded, though without being able absolutely to affirm it, were independent of the errors of the experiments, even counting among these the case of a voltaic current introduced for a moment into the circuit at Volterra, where I was not present.

The last series of experiments which I shall report, relates to observations made on a long telegraphic line from Ivrea to Courmayeur, first in October, 1864, and again in November, 1866. These experiments were made in three different sections, of which that line is composed. The first, between Ivrea and St. Vincent, nearly parallel to the meridian, is 36 kilometres (22 miles) in length, with a difference of level between the extremities of 281 metres, (922 feet.) The second section between St. Vincent and Aosta is 25 kilometres (16 miles) long, and the difference of level, 83 metres, (272 feet.) The third, between Aosta and Courmayeur, at the extremity of the valley at the foot of Monte Bianco, is 27 kilometres (17 miles) long, and the difference of level of the two extremities 642 metres, (2,103 feet.) In 1864 the experiments were made separately in the three sections of the line; in those of 1866, only two sections, that, namely, between Ivrea and Aosta, and that between Aosta and

Courmayeur, were brought into requisition. The wire was the usual iron one, from 3 to 4 millimetres (⅛-inch) in diameter.

Before the experiments, the entire line had been inspected, repaired, and insulated with care, so that there was no sensible movement in the needle on introducing a current into the line, while the opposite end was insulated in the air. I employed the usual electrodes of zinc, immersing them in the water of wells when I could, or introducing them into holes made in the ground and filled with identically the same water, which was that of the Dora. Between Ivrea, St. Vincent, and Aosta, the experiments were always made in the night, when the telegraphic offices were closed; in the last experiments between Aosta and Courmayeur, where the telegraphic service ceases in September, the experiments might be made with confidence at any hour of the day. The results obtained in the first series of experiments, as heretofore described in the *Comptes-rendus* of the Academy of Paris, (September 19, 1864,) were as follows: The electric currents obtained in the three lines of the valley of Aosta, notwithstanding the much greater resistance of the metallic portion of these lines in comparison with the line of 600 metres, (1,969 feet,) on which I had operated in the hills near Turin, gave with the same galvanometer much stronger currents, measured by the deviations more or less fixed of 40°, 60°, and even 80°, instead of 20° to 25° at most obtained in the shorter line. At all times, when the deviations became fixed—and this was sometimes the case, even for the space of an hour—the deviation indicated an ascending current in the metallic line. But a certain tremor of the needle was noticed, and from time to time, as in the experiments between Pontedera and Volterra, the needle descended suddenly to 0°, about which it oscillated, or even passed into the opposite quadrant, returning afterwards to the fixed deviation prescribed by the ascending current of the wire. In this case, also, I have every reason to believe, though I will not absolutely affirm it, that no voltaic current was introduced at such moments into the circuit so as to produce the oscillations in question.

The experiments made in November, 1866, were conducted under better conditions when the correspondence between Courmayeur and Aosta had been suspended for two months. In these I was assisted by Signor Eccher, adjunct of the chair of physics in this museum, to whose zeal and love for science it is due that even under unfavorable circumstances of weather and place, especially in the winter, all possible precautions were used in order that the experiments might yield exact results. At each extremity of the line three similar vases of earth were sunk in a formation of nearly identical qualities at a certain distance from one another, and the current was measured by transferring in succession the electrodes of zinc immersed in porcelain cylinders and ascertained to be homogeneous, now to one and now to another of the earthen vases, all of which, at either extremity, were filled with water from the same source.

The experiments between Aosta and Courmayeur were made on the 3d of November, 1866, at 8 o'clock in the morning; the atmospheric electricity at Courmayeur was feebly positive; snow had fallen in the night on elevated places, and the clouds were dissipated only at the rising of the sun. At 8.45, the line was tested in order to ascertain its insulation, which was found to be perfect. The experiments yielded the following results:

Hour.	Deviation.	Limits of oscillation of the needle.	Observations.
9. 15 a. m.	30°	20°—43°	The extreme holes used which we will call No. 1 and No. 1'.
9. 30 a. m.	41	30 —51	Needle nearly firm, oscillating only between 38 and 45.
9. 45 a. m.	52	50 —55	Needle nearly immovable.
10 a. m.	....	....	The communications being withdrawn the needle goes to 0°; they are restored between holes No. 1 Courmayeur and No. 2 Aosta.
10. 10 a. m.	50	40 —55	
10. 20 a. m.	51	49 —54	Needle nearly firm.
10. 30 a. m.	52	50 —58	Slow oscillation
10. 40 a. m.	54	....	Absolutely firm.
10. 45 a. m.	....	....	Signs of positive electricity stronger than in the morning.
10. 58 a. m.	54	45 —60	Very feeble oscillation.
11 a. m.	....	....	Communications being withdrawn the needle goes to 0°; restored between hole No. 3 Aosta and No. 2 Courmayeur.
11. 10 a. m.	52	46 —60	Needle nearly firm.
11. 20 a. m.	52	46 —60	Idem.
11. 35 a. m.	47	30 —51	Between holes No. 3 and No. 3 of the two sides needle oscillates.
11. 45 a. m.	45	25 —50	Idem.
12 m.	....	....	Communications removed and restored between hole No. 1 Aosta and No. 3 Courmayeur.
1. 05 p. m.	36	30 —50	Small oscillations.
1. 10 p. m.	34	20 —42	Almost quiet.
1. 15 p. m.	36	20 —48	Oscillations; the holes are No. 1 and No. 1 of the two sides.
1. 20 p. m.	38	29 —50	Light oscillations.
1. 25 p. m.	42	35 —50	Scarcely oscillates.
1. 30 p. m.	....	....	Communications removed and replaced between No. 2 Aosta and No. 1 Courmayeur.
1. 35 p. m.	45	40 —52	Light oscillations.
1. 40 p. m.	49	....	Needle firm.
1. 45 p. m.	52	....	Idem; between the holes No. 2 on both sides.
1. 55 p. m.	52	....	Idem.
2 p. m.	....	....	Holes No. 2 on both sides.
2. 08 p. m.	48	40 —52	Nearly firm; holes No. 3 on both sides.
2. 15 p. m.	19	....	Needle firm.
2. 20 p. m.	50	45 —53	Light oscillations.

It is proper to add that at the two stations of Aosta and Courmayeur, two electrodes of copper were also in operation, consisting of two plates of that metal, with a surface of about a third of a square metre, and buried at a depth of about one metre. These plates were employed as electrodes after having been buried for two days. On the day of the 3d of November, with these electrodes of copper, and at intervals of some hours, there was a nearly fixed deviation in the same direction with those of the electrodes of zinc, and indicating, from 12 o'clock to 12.48, successively 65°, 70°, 69°, and from 2.40 to 3.30, 69° and 68°. All the deviations above reported indicated *an ascending current* in the metallic portion of the circuit.

I shall only cite, in addition to the above, the experiments made on the line between Ivrea and Aosta, having a length of about 160 kilometres, (99 miles,) and a difference of level between the extremities equal to 364 metres, (1,194 feet.) These experiments were conducted precisely like those just described at length, between Aosta and Courmayeur, and were executed during the days of the 5th and 6th of November. The atmospheric electricity, always positive, was at Aosta considerably more intense than in the experiments made at Courmayeur.

The current which circulated in this line was constantly an ascending one in the metallic part of the circuit, and for many hours the deviation oscillated between 40° and 50°. On the second day the air was perfectly serene, the sun lustrous, and the signs of atmospheric electricity constantly progressive. The needle remained deflected for several hours, and apparently fixed between 60° and 64° by an ascending current in the metallic line. Here also the plates of copper, sunk in the

ground at the depth of a metre, (3 feet,) were tried as electrodes, and the deviation obtained, the needle continuing nearly immovable, was from 64° to 65°.

GENERAL CONCLUSIONS.

The experiments described in this memoir point to the following conclusions:

1. If a metallic line be insulated from the ground or suspended at a certain height, or in actual contact with the ground, and its extremities be sunk in the earth, in good communication with the latter by means of perfectly homogeneous electrodes, with a certainty that there does not exist any electro-motive force between the parts of the metallic circuit, or between the earth and the electrodes, it will be found that there is in that line a constant circulation of electricity, whenever the line, having a rectilinear length of at least 6 kilometres, (4 miles,) has its extremities sunk very nearly at the same elevation and in a horizontal stratum, or, if the length of the line be much shorter, when its extremities are sunk in the ground at a different degree of elevation.

2. When a metallic line has a length of 6 kilometres, (4 miles,) and its extremities are sunk in a horizontal stratum, there is in that line a current having a constant direction from south to north, if the line be extended on the meridian; if the wire be extended in an equatorial direction, the signs of the electric current which circulates therein are very variable and without a fixed direction.

3. In a metallic line much shorter, say 300 metres (984 feet) to commence with, there is a constant circulation of electricity, if the extremities are sunk in the ground at a different elevation as regards one another. In that case, the current is one constantly ascending in the metallic line.

4. This ascending current has an intensity which, notwithstanding the greater resistance of the circuit, increases with the length of the circuits, and increases also with the difference of level of the points at which the extremities of the line are sunk. But in circuits which are of considerable length, and in which there is a great difference of altitude between the extremities, the intensity of the ascending current is not so constant as in short circuits.

These results change in the presence of storms, and also in great atmospheric perturbations; in such cases the intensity of the terrestrial current, and likewise its direction, are subject to very considerable variations.

Hypothesis respecting the origin of the terrestrial current.—I shall be very brief on this point, as these researches are still deficient in that extent which would be requisite for success in interpreting a phenomenon necessarily obscure and highly complicated when submitted to rigorous investigation.

When we consider that the resistance to the electric current of a terrestrial stratum is nearly null, and that it does not vary with the length of the stratum, it is not easy to see an analogy between these currents and derived currents properly so called.

Associated as the terrestrial currents are with the apparition of the aurora borealis, and with the great variations of terrestrial magnetism, the probability naturally suggests itself of an intimate relation between these currents and the causes of the magnetism of the earth, as well as of the electric state of the earth itself and of the air. If, as has been proved by experiment, the earth is a body charged with negative electricity; if, as in effect is the case, the tension of this electric state of the

earth increases with the altitude of terrestrial points, it can be conceived that a metallic line, one extremity of which touches the bottom of a valley and the other a summit, should be traversed by an ascending electric current, with an intensity proportional to the difference of the electric potentialities of the two points. Since, then, the electric state of the earth varies even in clear and calm days at the various hours of the day, the electric current of the earth also might derive, from that law of atmospheric electricity, its origin in metallic lines, touching the ground with their extremities, provided the lines be very long ones.

But phenomena so obscure and complex demand great reserve in any attempts which are made to explain them, and it is only from those new and persevering researches which we invoked at the beginning of this memoir, that greater light can be hoped for in regard to a phenomenon of so much importance in terrestrial physics.

LECTURES ON THE PHENOMENA OF FLIGHT IN THE ANIMAL KINGDOM.

BY M. MAREY, *of the College of France.*

[*Translated from the Revue Des Cours Scientifiques, for the Smithsonian Institution.*]

We shall occupy ourselves on this occasion in the discussion of a question which is connected with our first studies on motion, as one of the functions of life, namely, with the—

NATURE OF FLIGHT IN THE ANIMAL KINGDOM.

Flight is a process of locomotion, in some cases indispensable and in others accessory to the life of an immense number of living beings. It is not confined to insects and birds that live habitually in the air, or to certain mammals, such as bats, but is also common to animals which are essentially confined, by their organization, to a terrestrial or aquatic life, such as flying and dragon fish, gecko-lizards, and, above all, to pterodactyles, a race at present extinct. The field on which we are about to enter is very extensive; and although it has been long cultivated, it would not be surprising if we should find that it has not been entirely exhausted, or that it is still capable of yielding new facts.

In beginning, for the first time, the study of locomotion, we should address ourselves to the origin of the phenomena connected with the subject, and we would pause upon the elementary apparatus which is its special organ, namely, *muscular fiber*, and also upon the elementary function of this indispensable organ, namely, *muscular contraction.* We have, however, considered these in their general application to motion in previous lectures, and need only recall them to mind in this place. The evident manifestation of animal motion is the production of a change of place, or locomotion; but what we are now to consider especially is aerial locomotion or flight.

Animal motion presents a series of complex phenomena; for example, when we bend a finger, and examine the series of events which occurs in the production of the desired result, we find, at the beginning, first, the operation of the will, or a *psychical action;* secondly, the transmission of the influence of the will, or a *nervous action;* thirdly, the contraction of the muscles, or *muscular action;* and, fourthly, the motion of the finger, which is a *mechanical action.* In the study of these phenomena with which shall we commence? A philosopher of the past, a Spinozist, would not hesitate in answering, but would say at once, the logical order should be observed; the examination of the action of the will should be first made; and the other phenomena deduced from the result of this, as the primary cause. But this method is the one which the modern school of science rejects. The investigators of our day reverse this order, and, instead of descending from causes to effects, ascend from effects to causes, from more simple and evident phenomena to those which are more complex and hidden. If we first attempt to grapple with

the psychical phenomena in the series we have mentioned, we shall find ourselves at once encountering difficulties far beyond our power to overcome. If it be true, as has been said, that all investigation, when reduced to its ultimate element, is measurement, how can that be investigated which is beyond the reach of all measurement? What unit will serve to express in figures the phenomena of *intelligence*, *will*, and *sensibility?* These, although similar in some respects, and belonging to the same general class of phenomena, are so heterogeneous to others with which they are associated as to admit of no comparison. Physiologists, therefore, address themselves, as we have said, at first to the study of the phenomena which offer the most easy study, and these are almost always the last terms of a series of acts such as those which I have mentioned. Each successive discovery, then, facilitates further advance, and enables the investigator to rise toward results which at first appear unattainable, and to elevate himself almost to the level of those questions on which speculative philosophy has spent itself in fruitless efforts. We, therefore, commence with the study of muscular action. The first step in this was made when the unattainable influence of the will was replaced by the electrical stimulus; muscular contraction then commenced to be studied by itself, separate from all extraneous influences.

You know of what assistance in studies of this kind is the application of the graphic method with the registering apparatus. It was by means of this method, and the instrument called the myograph, that Helmholtz, in 1850, prosecuted his admirable researches on muscular action, and I was enabled to add my contributions to the theory of muscular contraction. The myograph enables us to note the exact instant when the phenomenon begins, its duration, and extent; while the curve traced on the cylinder makes known all the circumstances of its production. Now, the possibility of noting the precise instant of the muscular contraction furnishes us with the means of the examination of the second of the acts which form the object of our researches, namely, the transmission of the nervous force.

Up to a very recent date, even as late as 1845, it was thought that sensitive impressions were transmitted to the brain from the extremities, and that the impulse of the will returned with the rapidity of lightning, the time necessary for the transmission being regarded as infinitely small; and, indeed, some physiologists, Müller among others, contended that this point never could be settled by science. The honor of falsifying this prediction belongs to Helmholtz, who carried out, in 1850, a programme of experiments, suggested by Du Bois-Raymond five years before. He proved that the time taken by nervous force to traverse the length of a specified nerve could be accurately measured. After him, Valentine, Du Bois-Raymond, Donders, and Marey repeated the experiments, and considerably simplified the method of operation.

In all the researches the plan which was followed consisted, first, in exciting a nerve in the neighborhood of the muscle to which it belonged, and determining the interval which elapsed between this irritation and the contraction which resulted from it; secondly, in stimulating the nerve at a greater distance from the muscle, and determining how much longer contraction was retarded than in the former case. This delay necessarily follows from the greater distance which the nerve-impulse has to traverse in the second case, and thus indicates the rapidity of this agent along the nerve which has been operated upon, or, in other words, furnishes the means for the deduction of the absolute velocity of the nervous impulse. Helmholtz found that about 0.00175 of a second was occupied by a nervous impulse in traversing a distance of forty-three millimeters,

which corresponds to a velocity of twenty-six meters per second. This velocity, however, varies somewhat with the conditions of the organ on which the experiment is performed. I shall not dwell on these points, which are already published, but shall call your attention to this remarkable fact, bearing directly upon our thesis, namely, that the measurement of the nervous transmission enables us to rise to the study of psychical action. "Has thought no longer the infinite rapidity which has been habitually attributed to it, and is it possible to measure the time necessary for the formation of an idea or a determination of the will?" Such are the terms in which Donders expresses the problem.

The first researches on this interesting subject are due to the astronomers. Toward the year 1790 a curious fact was announced by Maskelyne, who stated that in the estimation of the passage of stars across the thread of a meridian telescope, there was a constant discrepancy between his observations and those of his aid, Kinnebrock. Later, Bessel, comparing the observations of other astronomers with his own, perceived that most of the observers signalized the passage of stars a little later than he did, the difference in some cases being more than a second. These observations attracted the attention of astronomers generally. They commenced to study the phenomenon under the name of the *personal equation*, and to ascertain its absolute value. To illustrate the method of obtaining this result, we shall only describe the process lately invented by M. Wolf, of the Paris observatory. He arranged a luminous bull's-eye, a kind of artificial star, so that it moved at a uniform rate along a curved line, resembling the trajectory of a true star. At the moment this luminary actually passes before the thread of the telescope, or at the moment when its center coincides with the central thread, it closes the circuit of a galvanic battery; at this precise instant, an electric current, excited by the completion of the circuit, records the passage of the star on a revolving cylinder. Moreover, the observer, at the moment when he perceives the passage of the artificial star before the thread of the telescope, by pressing a spring, records the instant on the same chronograph. The interval between the two signals, estimated in fractions of a second, measures the lapse of time between the real passage of the star and the estimation of its passage by the observer. This is the absolute value of the personal equation, which remains nearly the same for each observer, unless, being aware of it, he endeavors to correct it. M. Wolf reduced his error from three-tenths to one-tenth of a second.

From a physiological point of view, we may ask, What is this personal equation? The astronomers, Bessel and Faye, have suggested the hypothesis that an intellectual operation is necessary for transmitting by a signal a perceived sensation. The phenomenon has not the less generality from having been at first signalized by astronomers, and it may be said that a certain time always elapses between the instant of occurrence of a phenomenon and the signal of an attentive observer that he perceives it. The duration which separates the impression from the signal of the reaction has been called the *physiological period*. We owe very curious observations upon the variations of this physiological period to M. Hirsch, (of Neufchatel,) and especially to M. Donders, and his pupils.

Thus, the signal of reaction being always the same—for example, a motion of the hand, as in closing a galvanic current—it is observed that the signal is produced more rapidly if the impression is made upon the sense of hearing than if it is exercised upon the sense of sight, and still

more quickly by tactile irritation. If the impression is on the eye, the reaction of the hand takes place in one-fifth of a second; if it is on the ear, in one-sixth of a second; and on the skin, in one-seventh of a second. Thus the physiological periods are among themselves as the numbers one-fifth, one-sixth, one-seventh. But does this period of, for example, one-seventh of a second, which elapses between the moment when the skin is irritated and that when the observer moves his hand, correspond entirely to a psychical act? We answer no; it is necessary that the sensory impression should have time to reach the brain; cerebral perception and volition being then accomplished, time is required for the motor impression to reach the muscle and determine its motion. Nor is this all. The impression once produced passes through the nerve with a known velocity, but this impression is not instantaneously produced; it needs time to take form, to be completed before becoming ready to traverse the nerve. It is not sufficient, therefore, to deduct from the total duration of one-seventh of a second, the duration of the passage of the sensory nerve-force and of the motor nerve-force, to conclude that the remainder appertains to the psychical act. These experiments do not exhaust the subject. They do not make known the duration of the cerebral act, nor even whether it has a duration.

M. Donders instituted in the meanwhile a series of experiments destined to remove all doubts. His method consists in augmenting the physiological period until the measurement of the intercalated intellectual operation can be clearly observed.

The following is the plan of one of his experiments:

First case.—The observer knows that an electric shock will be given to his right foot, while the signal of reaction is to be given by the right hand.

Second case.—The observer does not know which foot will receive the irritation, and is instructed to give the signal by the hand of the irritated side.

The physiological period measured in the two cases was longer in the latter by about one-fifteenth of a second. It is clear, all the other conditions being the same, that the difference in question represents the time necessary to determine upon which side the irritation had taken place, and to direct to the right or left side, conformably with the idea acquired, the action of the will. Consequently the solution of a dilemma reduced to the most simple form is a cerebral action existing during one-fifteenth of a second. It is thus experimentally established that a cerebral action has a duration. We finally become assured that this duration is augmented in proportion as the psychical action becomes more complicated, and that it is diminished when the action becomes simplified.

Instead of exciting the organs of touch, Donders next experimented as follows on visual irritation:

First case.—The observer executes a movement with the right hand upon the appearance of a white light.

Second case.—A white light and a red light are employed, and the signal of reaction is to be given with the right hand for the white light, and with the left hand for the red light. Under these conditions the solution of the dilemma consumes in the mind a more considerable time. On the contrary, in the case of auditory stimulation, the dilemma was solved by the mind in less time than in the case of visual stimulation. The author of these researches attributes this superiority of one sense over another to a facility derived from habit or exercise; and, in fact, repetition tends to equalize the action in the case of the two hands.

The elementary psychical action which we have examined has not yet attained the greatest degree of simplicity. Since, in the solution of the preceding dilemmas, two operations of the brain can be distinguished—first, the distinction between different impressions; second, the volition of an act chosen from among other acts—Donders asked himself if it might not be possible to determine separately the time appertaining to each of these two terms. The following is the experiment which he instituted to attain this object:

First case.—An observer was warned that a vowel would be pronounced, and was directed to reproduce the sound heard.

Second case.—The observer in this second arrangement was directed to respond only to a single vowel—*i*, for example—and to keep silence for all others pronounced. His effort was then entirely directed toward the recognition of *i*, the vocal organs were placed in the proper position, and the impulse of the breath alone was needed to emit the corresponding sound. We readily comprehend how much the second term of the psychical action is simplified under these conditions. The will having only to apply itself to the production of such a sound, rather than any other, reacts, so to speak, without a previous judgment, and the signal follows the act of volition as simply as can be imagined. We naturally observe that this restricted operation occupies less time than the first by the amount of time necessary to respond to each sound with its equivalent, and this difference corresponds to the action no longer required by the brain.

The preceding considerations indicate sufficiently the path which we have to follow. Having to study the function of aerial locomotion, we shall examine the organ which serves to accomplish it, namely, the wing. It is by the movements of their wings that animals sustain and direct themselves in the air. They strike the atmosphere with repeated blows, and the reaction of this fluid on the surface which they expose serves for the propulsion of the entire body.

I.—Flight of insects.

The first subject which presents itself for our investigation will be the inquiry as to the frequency of the motions of the wings of insects. Here we encounter the first difficulty. The movements of the wings are so rapid in most cases that the eye cannot count or follow them. There are very few insects which fly slowly enough to render this direct determination possible. Among the most common we may mention the white butterfly which is frequently met with in our fields, the cabbage *Pieris*. This insect, which has a jerking flight, seldom executes more than eight or nine movements of the wing in a second; while those insects whose flight is directed with precision and without jerks toward a determined point generally execute hundreds of strokes of the wing in a second. Thus, in the majority of cases, direct observation cannot follow the wing of insects. We observe a body in motion, but we only perceive the extreme limits of its oscillation; it may, however, be said that these limits are seen with great precision. But that observation may be facilitated, it is necessary that the subject of it shall be placed in a favorable situation. We take, for example, one of those *Macroglossa* (sphynx moths) which frequently serve as the subject of experiments on account of their large size and the readiness with which they are obtained. Fastening its body with a pin between two strips of cork in such a way that it shall not turn around upon the axis which pierces it, and that the motion of its wings alone shall be en-

tirely free and placing it before us, the wings being in motion, we perceive two oblique lines, which mark the limits of passage of each of its wings, while their intermediate positions continue to escape the most acute observation.

It is hardly necessary to give an explanation of this fact. Every time that a body in rapid motion changes its direction to return on its steps and to traverse in a contrary direction the road which it has already traveled, a moment arrives when its motion, before change of direction, becomes absolutely nothing; this point of cessation, this dead-point, is the extreme limit of oscillation. This is why the impression is produced before the wing has left the limiting position, and at the moment when the impression is about to be effaced the wing has had time to make a complete oscillation and to return to its point of departure, so that the new impression is confounded with the old one, and the eye experiences a continuous sensation, the result of the fusion of the intermittent sensations. But since the optical method is insufficient to inform us of the frequency of the vibrations of the wings, we must have recourse to another process. I may say, in advance, that the graphic process is the most exact of any we possess, and you shall be the judges of the results it will afford us. However, before broaching this new subject I cannot dispense with saying a few words on an ingenious method based on the observation of the sound which insects produce during their flight, and which we may designate as the acoustic method.

Every one has heard the sound which insects produce while flying. If this vibratory buzzing is due to the strokes of the wing, and if they result from its alternate motion back and forth, as the sound of the reed results from the vibration of a metallic lamina, then in ascertaining the pitch of the sound the number of alternate vibrations to which it corresponds will be known. For this, a tuning-fork, or a piano, is sufficient, with which we can compare the pitch of the sound produced by the insect. This method would be very conclusive if the principle upon which it rests was incontestably established. But on this point there is a difference of opinion among naturalists. First, a number of sounds produced by insects can be definitely excluded, which are certainly not produced by the vibration of the wings. Certain coleoptera, for example, produce sound by rubbing the last upper segments of the abdomen against the elytra.* T. Lacordaire cites, among the insects which emit sound in this manner, the *Necrophori*, the *Copri*, the exotic *Scarabi*, and a host of lamellicorn beetles not found in Europe. Almost all the lamellicorns produce a deep sound by rubbing the peduncle of their mesothorax† against the prothorax‡ in which it is inserted. Certain of the *Cicindelidæ*, the *Oxycheila tristis*, the *Melasomidæ*, the *Cacicus americanus*, rub their thighs or their hinder legs against the border of their elytra, producing in this way a peculiar noise. Ollivier, in the first volume of his entomology, mentions the fact that the female of a Cape of Good Hope insect, the *Moluris striata*, calls the male by rubbing a granular protuberance upon the lower part of the second segment of the abdomen against extraneous objects. Finally, among the crickets one part of the anterior wings, thinner than the rest, forms a kind of drum or tympanum; one of the nervures which traverses this drum is armed with denticles, on which, during the alternate motion of the wings one over another, the

* *Elytra:* the hard outer wings of beetles.

† *Mesothorax:* the second segment of the middle or leg-bearing division of the body of a beetle.

‡ *Prothorax:* the first segment of the same.

salient border of the opposite wing is rubbed in such a manner as to sound the drum and produce the noise familiar to every one. It will be understood that at present we eliminate all these sounds, the origin of which is evidently different from that of the vibrations of the wings, and confine ourselves to the very great number of cases in which the buzzing of the insect is manifestly produced by the rapid strokes of these organs.

Chabrier and Lacordaire report that a portion of the wings of most insects can be destroyed without a cessation of the sound. "In portions, as pieces of these organs are cut off, the sound becomes sharper, and sensibly more feeble, especially when we leave only a stump remaining. If this last be removed, which can only be done by a considerable laceration of the muscles which attach it to the thorax, the buzzing ceases entirely." "If," concludes the author, "the buzzing were entirely due to the wings, we could not cut off with impunity three-quarters of these organs." This objection confirms the hypothesis which it apparently was intended to disprove. In effect, since the sound is elevated in the same ratio in which the vibrating wing is diminished in length, is not this phenomenon entirely analogous to that which we observe when we have shortened a vibrating rod? The modification produced in the sound being the same in both cases, should not the mechanism of its production be identical? At least the facts cannot be regarded otherwise, if the vibrations of the wings are really the cause of the buzzing.

The authors whom we have just cited have indicated an entirely different cause for the acoustic phenomena. They have attributed them to the air which enters the tracheæ, and which, passing rapidly outward, puts in vibration the little scaly organs which surround the base of the stigmati.* And they cite, in confirmation of their views, this fact—that the buzzing also ceases if the surface of the body of the animal is covered with gum so that the excess of air to the respiratory canals is prevented. The lips of the stigmati act as the lips of the glottis do in superior animals, and the buzzing of the insect, therefore, becomes a true voice. Whatever may be the fate of this explanation, the result which we desire remains the same. We see, in effect, that in the motions of the wing there is, as it seems, only a single active period—that in which it is lowered, brought down; the elevation takes place in consequence of the elasticity of the pieces of the thorax strongly stretched by the contraction of the muscles which pull down the wing. At the same time that this tension is produced, the volume of the thorax is amplified and the incursion of air is the immediate result of this increase of capacity. The air must then enter and leave the tracheæ at each stroke, and the vibrations it produces (whether proceeding from the wing membrane or from the stigmati) correspond exactly to the movements of the wing.

The acoustic phenomenon, if it is not the consequence of the vibration of the wings, is at least synchronous with it. It can inform us, therefore, in all cases of the frequency of the strokes. When the buzzing of an insect, flying with a uniform rapidity, is observed, we find that the pitch perceptibly does not remain the same; when the insect approaches the ear the pitch is elevated, and is lowered when the insect flies from us. Something analogous takes place when a tuning-fork in vibration is moved rapidly to and from the ear; the sound becomes elevated and then lowered, and the difference may attain a quarter or even half a tone. It is necessary, therefore, to take care that the insect experimented on should always be at the same distance from the

* *Stigmati:* the spiracles or openings in the external integument of insects, through which respiration is carried on.

observer. This perturbatory phenomenon has been perfectly explained as follows: The vibrations, without doubt, are all produced at equal intervals of time, and, therefore, when the instrument remains at the same distance from the ear, the same time elapses between the several impulses on the tympanum. But when the fork is made rapidly to approach the ear the impulses are crowded together, and consequently the pitch rises; when, on the contrary, the fork is rapidly removed from the ear the impulses are wider apart, and the sound deepens. Every one has remarked, in traveling by rail, that if a locomotive whistles while passing in an opposite direction, the sharpness of the sound increases as it approaches, and becomes deep when it has passed and is rapidly becoming more distant.

II. *The movements of the wing of insects.*

To arrive at a complete comprehension of the mechanism of flight of insects, I have said that we should, in the first place, resolve a certain number of practical questions which should serve us as steps to reach a definite conclusion. I could present you immediately with the final result of the experiments by which I have elucidated this subject for myself, and the theory which expresses them, but I prefer to proceed otherwise. I shall enter on an examination of the facts and into the details of the experiments, in order that my hearers may participate more completely in the studies which we pursue together, for I am persuaded that there is as much profit in knowing how to arrive at a result as in knowing the result itself.

1. We have begun to study the motions of the wings, and the first question which presents itself is the frequency of these motions. On this point direct observation is of little assistance; the acoustic method, which consists in determining the frequency of the strokes of the wing by the pitch of the buzzing of the insect is more efficient, but we have seen that even the principle of this method has been contested, and that its application presents difficulties. The graphic method remains to be considered. This method consists in making the wings themselves record the strokes which they execute. When an insect is held in captivity by force which it cannot overcome, after trial it ceases a useless resistance; it resigns itself and abstains from all efforts to escape, its wings remain immovable, and in this way the observer who hopes to study their motions finds himself disappointed. But there are different methods of awakening the insect to its original activity; it is sometimes sufficient to pinch the antennæ lightly; this irritation of a very sensitive organ succeeds with the *Macroglossa*. Among the wasps the end may be attained by titillating the feet, or by holding them all together with a pair of forceps, and then releasing them suddenly, except one, by which the animal is held. The captive supposes that it is at liberty, and makes an effort at flight which last about thirty seconds, or long enough to be observed. There is, however, another difficulty. The captive insect, when willing, cannot fly like an insect at liberty, because the external conditions are not the same. It experiences a greater resistance in proportion to the traction which it exerts upon the bond which holds it; to a free insect the relation is such as a boat held by an obstruction bears to one sailing freely, or as a horse which drags a load to one relieved from harness. This resistance modifies its behavior considerably, and obliges us to distinguish between the two different conditions of free flight and flight in captivity. It is indispensable to establish these distinctions, in order to appreciate at their true value the results to

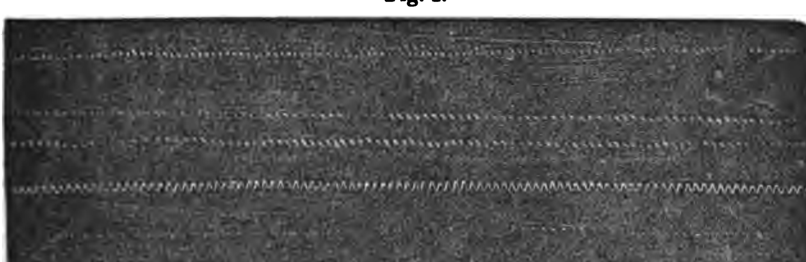
which we are conducted by the graphic as well as the other methods which we may employ.

The apparatus on which the wings record their motions is the ordinary registering apparatus, consisting of a metal cylinder covered with smoked paper, to which a uniform rate of motion is imparted by clock-work. Let us suppose that, instead of the motions of the wings, we would simply register the oscillations of a vibrating rod. For this purpose the extremity of the rod is furnished with a little style which touches the blackened paper with its point, and, as the different parts of the movable cylinder pass successively before the point, the soot is detached from the places which it touches and a trace produced. If the rod is not in vibration, it makes a long white rectilinear trace without sinuosities, a straight line which, rolled upon the cylinder, constitutes a circumference. If it is in vibratory motion, its trajectory will be a curved line, of which the sinuosities indicate all the circumstances of the motion, its phases of elevation, its depressions—in a word, all its movements—and consequently all the oscillations which the vibrating rod executes in space will be faithfully reproduced on the paper. If we would ascertain the frequency of the oscillations, it is sufficient to know the rate at which the cylinder revolves. Ordinarily a tuning-fork is employed, of which the number of vibrations is previously known, as, for example, one hundred vibrations per second. This is made to write its vibrations upon the registering cylinder below the line traced by the vibrating rod, of which the number of vibrations are desired. The comparison of the two tracings shows at once the number of the motions of the tuning fork back and forth, that is to say how many hundredths of a second correspond to one oscillation of the rod; the number of motions of the vibrating body during a given time is thus known with great exactness.

It is not, however, as easy to obtain the tracing from the wing of an insect as from a vibrating rod, and this for several reasons. In the first place it is very difficult to fix at the extremity of the wing a writing style; however light it may be, the rapidity of the motion to which it is submitted is sufficient in most cases to throw it off. If, however, after many trials and much precaution we are able to retain it in its place, a permanent cause of perturbation still exists from its very presence. Under the influence of this incumbrance the extent and frequency of the strokes of the wing are evidently diminished. It is easy to convince ourselves of this by taking a *Macroglossa* and fixing it in the manner which we have previously described, that is, immovably between two strips of cork, by means of a pin. Looking down upon it we perceive the extreme limits traversed by the wing above and below which we have called the *dead-points*. If some substance is applied to the surface of the wing, we see by the effect of this burden, in diminishing the play of the organ, the two limits of oscillation approach one another, and the extreme upper position, which just now was almost vertical, inclines towards the horizontal. We may finally remark that it is only at the cost of considerable chafing against the surface of the moving cylinder that we can obtain a complete tracing of the movement of the wing. The wing cannot touch the cylinder except during a very short instant of its stroke; that is, the instant when the wing reaches precisely the distance from the body of the animal to the cylindrical surface. The spherical figure which the margin of the wing describes in space, cannot have more than one point in common with the blackened cylinder. We can therefore only obtain, as the whole impression, a series of points at more or less regular intervals; and, if a more pro-

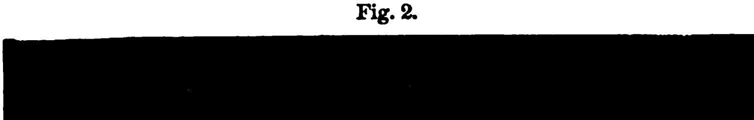
longed contact is desired, it can only be by curving the wing and folding it upon itself, and consequently the natural curve which the organization of the insect obliges it to traverse will be falsified and altered. In any case the friction against the blackened surface will retard the motion, and although the retardation which it causes may be neglected when it is opposed to bodies of large size, such as a tuning-fork or a vibrating rod, it cannot be when the vibrating object is the delicate membrane which constitutes the wing of an insect. Again, the friction, although exceedingly small, is found fully comparable with the forces which come in play in the motion of the wing, and its intervention notably alters the action of the latter. Experiment has confirmed these views. In one case an insect executing the motions of flight, and rubbing its wings somewhat roughly against the paper, furnished 240 movements per second; by diminishing more and more the contact of the wing with the cylinder, there have been obtained 282, 305, and 321. If, therefore, we would have a faithful representation, it is necessary to renounce the idea of obtaining those beautiful, regular, and continuous lines which are produced by the tuning-fork or vibrating rod, and content ourselves with interrupted lines, half-strokes represented by fragments, or even only isolated dots, the periodical return in these incomplete markings of definite forms permits us to infer the repetition of similar oscillations, and hence to determine their frequency. The operation is as follows: With a delicate pair of forceps we hold the insect by the lower portion of its abdomen, in such a position that one of its wings at each movement shall lightly touch the blackened paper. Each of these touches takes off a portion of the soot which covers the paper, and, as the cylinder turns, new points incessantly present themselves to the contact of the wing. A figure is thus obtained, formed of a series of points or short strokes of perfect regularity if the insect has been maintained in a fixed position.

Fig. 1.



Showing the frequency of the wing-strokes of a drone, (the three upper lines,) and of a bee, (the lower line.) The fourth line is produced by the vibration of a tuning-fork, furnished with a style, which executes 250 double vibrations per second.

Fig. 2.



Tracing produced by the wing of a drone rubbing a little more strongly on the paper than in the preceding figure.

We have obtained a large number of these tracings in which the wing has only touched the surface of the registering cylinder, and has left

only a point as a mark in each of its vibrations. I exhibit a number of these, and trust as soon as the return of spring permits us, to procure insects to show you the experiments by which these tracings have been produced. Those which you are now examining have enabled me to determine the frequency of the strokes of the wings of the following insects:

	Strokes per second.
Common fly	330
Humble-bee	240
Honey-bee	190
Wasp	110
Sphinx moth, (*Macroglossa*)	72
Dragon fly, (*Libellula*)	28
Cabbage butterfly	9

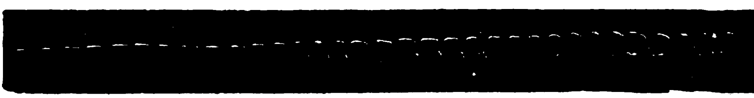
Certain authors have estimated this number of vibrations by the acoustic method, but there is a notable discrepancy between the above figures and those which they have deduced from the pitch of the sound that these insects produce in flying. In the case of the common fly, T. Lacordaire has computed the number of the vibrations of its wings at 600 per second, that is to say, twice as many as our figures exhibit. Has there not been a misunderstanding here, as is frequently the case, in the use of the word "vibration?" Some persons wrongly consider the raising and depressing of the wing as two vibrations, and reserve the term of "simple vibrations" for one or the other of these isolated motions. On the contrary, if we follow the usage most generally adopted, the two motions together, by which the body is again in its original position, should be considered as a single vibration.

The previous observations which we have made on free flight, and on flight under restraint, somewhat curtail the range which we are tempted to accord to these numbers. The animal, according as it desires to move with a greater or less rapidity, can change at will not only the extent of its wing-strokes, but also, to a certain extent, their frequency. Fatigue may exercise an analogous influence to that of the will; after very rapid motions, the exhausted animal diminishes the number of its strokes, which sometimes falls to a fourth or a fifth of its normal value. It continues to relax them more and more until a period of repose and reparation permits it to resume its usual flight; nevertheless the examination of these numbers suggests some general considerations. We have reason to think that each of the muscular contractions which determine the drawing down of the wind is the result of a single impulse, (*Zuckung* of the Germans,) although in man contraction is due to successive impulses which are merged in one another when they are produced more frequently than 30 times in a second. Among insects the limit of fusion of impulses is infinitely more remote, and ends with leaving the wing immovable in a sort of permanent tetanic contraction. It is easy to assure ourselves of this by means of living insects, or better, by means of the artificial insect which I have constructed. When the impulses become too rapid, their extent diminishes; at this moment they no longer serve for the propulsion of the animal, whose wings appear quite immovable or merely agitated by a light tremor. Nevertheless, the number of muscular waves which the fibers of insects will admit without intermingling, a number which in the fly amounts to 300 per second, forms a physiological fact, very interesting to note. Among other animals the limit is not so remote; among birds fusion is produced after 75 impulses; among mammals after 30, and among reptilia after only 4. These dif-

erences correspond, in virtue of the relations which I have long since explained to you, to analogous differences in the rapidity with which the elementary impulse traverses the muscular fiber of these different animals. The muscular fiber of the insect will then be characterized, physiologically, by the property which it possesses of furnishing a considerable number of distinct impulses, as well as it is anatomically characterized by its relative size and its striation.

The graphic process which enables us to judge of the frequency of the strokes, also permits us to show the perfect synchronism of the play of the wings. For this purpose it is necessary to choose an insect of which the amplitude of the wing-vibrations is large, so that in their moment of greatest elevation they may nearly meet above the dorsal region of the animal. If the insect is placed near enough to the registering cylinder, the dorsal region turned toward the blackened surface, it is clear that at the moment when the wings approach each other they will leave their traces on the paper, thus describing a series of loops and curves, of which the perfect correspondence proves the synchronism of the motions from which they originate.

Fig. 3.



Simultaneous tracings of the wings of a wasp in short flight. The perfect synchronism of the two wings will be observed.

Furthermore, we can convince ourselves that a sort of necessary connection exists between the motions of the two wings. If we throw an insect violently upon the ground, so that it is stunned and can no longer execute voluntary motions, we observe that, by producing motions in one of the wings, the other follows, to a certain extent, the movements inflicted on its fellow. If one of the wings of an insect is depressed, the other also bends down; if one be raised the other elevates itself. Certain species, especially the wasp, lend themselves very readily to this experiment. According to Chabrier, the author of an extensive work on the mechanism of the flight of insects, synchronism cannot fail to exist. This author considers the depression of the wing as the only effective portion of the stroke; its elevation is a passive phenomenon due to the action of physical forces. In fact, after the depression each dorsal arc of the thorax is deflected like a bent bow, and when the muscular contraction ceases the bow springs back in virtue of its elasticity, and the wing is raised. Now, if the pressure did not act simultaneously on the two extremities of the bow it could not be flexed as it is, and the mechanism which we suppose would be impossible. The reality of this synchronism is, then, a strong proof in favor of this manner of understanding the motion of the wing.

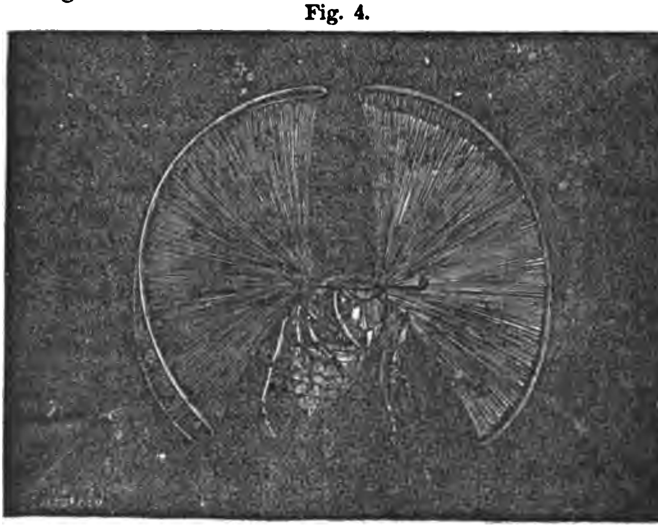
After having determined, in a general manner, the frequency of the vibrations of the wing, we seek to know the variation produced in the number of these vibrations by agents capable of influencing the activity of the animal. In the first rank of such agents must be placed heat and cold. We know that warm, dry weather is essential to insects, especially coleoptera, to enable them to fly well; special observation has confirmed this fact. We are able to state that, within certain limits, the frequency of the strokes is augmented with an increase of the temperature, and that they become slower under a gradual increase of cold.

II.—Form of the motions of the wings.

After having studied the frequency of the vibrations of the wings, it is necessary to study their form. For the end which we desire to obtain—that is, to arrive at a theory of the flight of insects—the most important element to comprehend is that which we now proceed to investigate, namely: The form of the trajectory which the wing describes in space instead of the rapidity with which this trajectory is described. In order to arrive at this determination we shall have recourse to two processes which will reciprocally correct each other—the optic method and the ordinary graphic method.

Optic determination of the movements of the wing.—When a brilliant body moves with rapidity it leaves upon the retina a kind of luminous train which acquaints us with the trajectory through which the body has passed. Children sometimes amuse themselves in producing the most varied figures by brandishing in the air a stick having one end on fire. It is on this principle that the apparatus known in physics under the name of *Wheatstone's calidrophone* is founded. This is a rod, fastened upright on a heavy foot, to which complex vibrations may be given, and to the ends of which a brilliant metallic bead has been affixed. If the rod is put into vibration the brilliant bead describes in space luminous figures which vary with the different combinations of the vibratory motions. If a brilliant spangle can be attached to the extremity of the wing of an insect, this spangle, traversing without cessation the same points in space, leaves a continuous luminous figure, exempt from the imperfection which is caused by friction in the case of the graphic cylinder. The extremity of an insect's wing can thus be rendered brilliant without mutilating it in any way; it is sufficient to place upon it a drop of varnish, to which a small piece of gold-leaf is applied. The varnish dries so rapidly that the insect cannot throw off this little reflector of light, and nothing more is necessary than to hold the animal in a fixed position to observe the play of light upon the small brilliant surface. Under these conditions the bee and the wasp furnish a well-marked "figure of eight."

Fig. 4.



Aspect of a wasp, the extremity of whose primary wings has been gilded. The animal is supposed to be placed in a ray of light.

The figures of eight are more or less widened or compressed according to circumstances. Sometimes the point of the wing seems to move almost in one plane. In the dragon fly (*Libellula*) a figure of eight is also observed, but much more elongated; the loops are narrow and laterally compressed. With the *Macroglossa galium* it sometimes seems as if the preceding form had disappeared, and is replaced by a sort of ellipse. However, in examining it closely it is soon perceived that this ellipse is surmounted by a little loop, very slightly developed, relatively to the curve which supports it. It seems that one of the loops is enlarged at the expense of the other, but this last has not entirely disappeared, and the vestige what remains testifies to the persistence of the figure of eight which is encountered in most other cases, and which may serve as the general type.

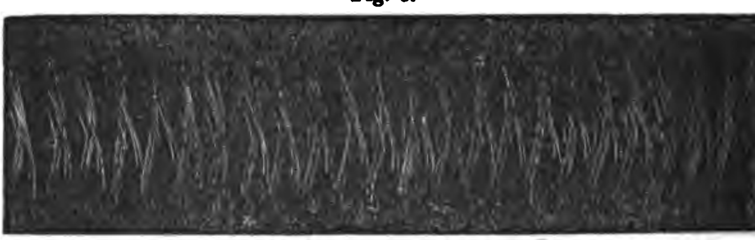
Changes of the plane of the wing.—The luminous figure which the gilded wing of an insect gives in its motions also shows that, during the alternate motions of flight, the plane of the wing changes its position in relation to the axis of the body of the insect. During the period of elevation the upper face of the wing is directed backward, while it turns a little forward during its descent. In fact, if we gild a large extent of the upper face of the wing of a wasp, taking care that the gilding shall be limited to this face, it is seen that the insect, placed in a ray of light, gives the figure of eight with a very unequal intensity on the two sides of the image, as is seen in the preceding figure. It is evident that the cause of this phenomenon is found in a change of the plane of the wing, a change in consequence of which the angle of incidence of the solar rays, while favorable during the ascent of the wing, is unfavorable during the descent. If the animal is turned so that the luminous figure is observed inversely, the figure of eight presents, in an inverse position, the striking inequality of its two halves, catching the light in a portion which was just before without it, and losing it where it had previously shone. We further find, in the employment of the graphic method, new proofs of the changes of plane in the wings of insects during flight. This change of plane is of great importance, for in this rests, as we shall see, the immediate cause of the propulsion of the body of the animal by the application of the motive force.

Method of contact.—Does the extremity of the wing really describe this double loop which we perceive, or is this form the result of an optical illusion—a play of light? Though such an objection is hardly probable, it is necessary to refute it. To assure myself more entirely of the reality of the displacement of the wing than the optic method rendered perceptible, I have introduced, while the wing was in motion, the extremity of a little bodkin into the interior of the loops of the figure of eight, and I have established that in the interior of these curves free spaces really exist, of a funnel shape, in which the bodkin penetrated without encountering the wing, while if I attempted to touch the intersection where the lines cross the wing immediately struck against the bodkin, and flight was interrupted. Still greater precision can be brought to bear on the appreciation of these motions, and, knowing that the wing describes a double loop, it may also be known in what manner it transverses the branches. It is sufficient to bring near to the wing in motion a leaf of paper blackened on both sides; the wing, in pursuing its course, strikes against one of the sides of the paper, and the trace which it leaves testifies to the manner in which the motion is accomplished.

Graphic method.—This method is not applicable to our problem without important modifications. We have just seen that it is difficult to

obtain tracings of any extent, because the wing cannot remain long in contact with the blackened cylinder, which it leaves and approaches successively. Under these special conditions it is necessary to have resource to an artifice, and since it is impossible to obtain a satisfactory trace at a single stroke, we should try to divide the difficulty and separate the operation into several periods. The preceding experiments simplify the interpretation of the tracings very much, and we can reconstruct the figures which the optic method has indicated from the slender elements which they afford. I have considered in the complete course of the wing of an insect, such as is represented in Fig. 4, three distinct zones, of which I have obtained the tracings separately; an inferior zone, corresponding to the lower portion of the figure of eight, a median zone, and a superior zone corresponding to the middle and upper parts of this figure. Bringing together the tracings obtained in these three zones I have been able to reconstruct the entire curve. In registering the tracings of the median zone, figures much resembling each other are obtained, presenting the two crossed lines shown in Fig. 5.

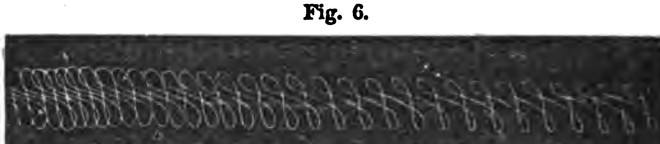
Fig. 5.



Trace of the median course of the wing of the *Macroglossa galium*, (Bedstraw sphynx-moth.)

The multiple tracings of the figure are formed by the fringed extremity of the wing, which presents many small points. The upper portion is in the form of a loop, as well as the part which corresponds to the lower course of the wing, and these three parts successively obtained give, when united together, the complete representation of a figure of eight, such as is obtained in acoustics in registering by Kœnig's method the vibrations of a Wheatstone's octave rod; that is, a rod which vibrates twice transversely for each longitudinal vibration. The slower motion of the cylinder produces the condensation of the end of the tracing.

Fig. 6.



Trace of a Wheatstone's octave rod.

The experiments can also be varied by obtaining, not the tracing of the point of the wing, but that of the anterior border of this membrane, striking laterally against the cylinder. It is clear that in describing the upper loop, this edge will approach the cylinder, then deviating; in a similar manner it will describe the lower loop, so that in its complete course it will rub twice against the blackened surface, and leave two white traces separated by an interval. This is observed in Fig. 7.

Fig. 7.

This figure shows from the tracing of the wing of a wasp the upper loop and the whole extent of one of the branches of the figure of eight. The median portion of this branch is only dotted on account of the feeble friction of the wing. We may, therefore, be permitted to conclude that if the trace of an insect's wing could be obtained entire at one operation, the same figure would be presented which we have seen described in space by the gilded spot on the wing of the wasp, namely, a figure of eight, which our ingenious acoustician, Kœnig, was the first to obtain with a spiral Wheatstone's rod, making two horizontal to one vertical oscillation.

It now appears to me sufficiently established that in the more extended motions of flight the wings of insects describe a figure of eight in space. Furthermore, that the luminous figure which a speck of gold on a wing presents in its motions has shown us that the periods of ascent and descent of the wing are accompanied by a change of plane in that organ. It is this fact which will shortly enable us to explain the mechanism of flight in insects.

III.—Mechanism of the Flight of Insects—How They Propel Themselves.

The preceding lessons have been devoted to the study of the frequency and the form of the strokes of the wings of insects. You have seen that the frequency varied in different species, and in passing from the butterfly, for example, to the house fly, or the gnat, the variations may be considerable. The flight of the butterfly is slow, the strokes of its wings succeed each other at considerable intervals, propelling it by bounds and jerks, and producing an irregular and capricious flight. The gnat darts with rapidity straight at its object, emitting along its path a clear, sharp, strident sound. Between these two extremes we find all intermediate stages. Furthermore, the same insect, under different conditions, varies the rapidity of its motions within extensive limits; when free from all restraint its movements are rapid and precipitous, but when captured they are immediately relaxed, and although the frequency of the movements of the wing varies, the form of the motion does not change. It is in all cases the same, always a double loop, a figure of eight. Whether this figure be more or less apparent, whether its branches be more or less equal, matters little; it exists, and an attentive examination does not fail to reveal it.

Before drawing from this fact the conclusions which it warrants; before extracting from it the solution of the problem with which we are occupied—that is to say, the mechanism of flight—let us rapidly review the history of the question, and see how far previous authors have advanced in its solution. Without going further back, we find in the work of Borelli a chapter devoted to this subject, in which he considers the force which the bird or insect must employ to sustain or move itself in space.

He estimates that this force is enormous; that it is, in the case of the bird, more than ten thousand times greater than the weight of its body. We still find this exaggeration in recent works. The academician Navier, falls into an analogous error, and after him M. Babinet accords, in his turn, a power to the inhabitants of the air far superior to that with which they are gifted by nature. However, by the side of these errors we find a great number of correct ideas, since confirmed by observation. Borelli knew that the principal motion of the wings was an elevation and depression, executed in a vertical plane, and he asked himself how it was possible that this motion, which, it seemed to him, could only serve to elevate the animal or to depress it, should nevertheless contribute to onward motion. For this, it was necessary that the vertical force should be changed into a horizontal force. Examples of this transformation are frequent. If a wind blowing horizontally strikes against a flat board inclined forward at an angle of, say, forty-five degrees with the horizon, the action of the wind will tend to throw it backward and upward; or, if the board is moving forward with a momentum, it will tend to elevate it. We have here an illustration of a well-known principle of mechanics—the resolution of a single force by an inclined plane into two forces—which gives in part an explanation of the flight of insects and of water birds. But insects have four wings instead of two. Is the office of these four organs the same; and if not, in what do they differ? Borelli does not treat of this question. It it discussed, however, in a particular case, by an anonymous author, who has left us an interesting manuscript on the habits of bees. This work, intended to complete and to correct the work of Réaumur, came from the Condamine Library, and belongs to M. Harnet. The author has observed bees at the moment when they hum at the mouth of the hive, trying to enter it and deposit their treasure. In examining the play of light on their trembling wings, he thinks that he saw the upper pair alone alternately raised and depressed, while the lower pair were animated only with a feeble horizontal motion. Here the question seems to have been abandoned, although the interest with which it is now regarded is far from inconsiderable. Beside the interest which it offers from the purely scientific point of view, in the mechanism of a function as widely employed as aërial locomotion, still another interest is attached to this study. The insect and the bird realize one of the oldest and most unsuccessful aspirations of the ambition of man. All space belongs to them; they go and come in the aërial ocean, while he is chained by his weight to the earth. Man has sought by various methods to escape from this confinement. The knowledge of the processes by which nature attains the end to which he aspires, would perhaps have spared him many fruitless attempts and loss of much time and great waste of invention. In 1823 a work appeared in which this question of aërial locomotion is treated *ex professo*, and no longer in an incidental manner. The author, the Chevalier de Chabrier, studied the conditions of mobility of the wing, and arrived at the solution of an important question: how muscular action is transmitted to this movable organ. Is it directly, or by some intervention? The muscle, responds Chabrier, is not directly attached to the wing; it acts upon the arch of the back. When it contracts, the curvature of this arch is augmented; when it relaxes, the back returns to its original curve, like an unbent bow. In the motion of the wing, therefore, there is only one active period, the moment of depression; the period of elevation is passive. Elasticity, therefore, plays an important part in this function. Here, as in all mechanical organs, it absorbs and then gives out power; it regulates speed and produces continuity of motion.

But Chabrier was soon carried away by an exaggeration similar to that of Borelli and of Navier, though in a contrary direction. According to him, an insect needed an insignificant force for its propulsion in space. No effort was necessary to sustain it in the atmosphere; the animal floated there like an inflated balloon. In order to fly, it filled its multitude of respiratory canals with air, and this, becoming heated, raised the animal as it elevates a hot-air balloon. It is not necessary to say that this conception of an *aerostatic insect* is an error. Without doubt an insect, before attempting a flight, lays in a quantity of air by a sudden respiration, but this provision of air contributes only an insignificant part toward the end which Chabrier assigned it.

The greater portion serves to prepare the organs of flight for the operation of their function. Jurine, of Geneva, in particular has shown that the nervures of the wing membranes are small tubes, which only acquire the rigidity and extension necessary to flight by inflation with air. We must refer to another contemporary, Strauss Durckeim, to find the elements of the theory to which my observations have conducted me. In his book on the Theology of Nature, a vast chaos of ingenious ideas, in which some profound, among many puerile, thoughts are to be found, there are many facts essential to the solution of our problem. Strauss Durckeim has conceived the ideal type of the insect-wing, the diagrammatic wing; that is to say, has reduced the organ to its essential parts. It consists of a rigid nervation or frame-work in front, a flexible web behind; this is all the apparatus. An apparatus thus constituted possesses the essential requisites for flight; otherwise constituted it will not serve this purpose, as is the case with the false-wing of the *Phryganidæ*, which has its principal nervation behind. It is enough that such a structure should be made to rise and fall successively; the forward border being ridged and the other flexible, it naturally disposes itself in an inclined position, receiving the reaction of the air obliquely, and thus transforms a part of the vertical impulse into a horizontal force. The two parts of the wing above mentioned are both indispensable in the same degree their respective offices complement each other in producing a single result. Ingenious experiments, due to M. Girard, throw light upon these facts. Destroy the anterior nervation, without removing the thin membrane, and the insect cannot fly; destroy the flexibility of the membrane by covering it with gum, and flight also becomes impossible. Here we cannot urge the objection that the superincumbent matter interferes by its weight like a burden which weighs down the animal; for, following out the experiment, we see that as soon as the coating becomes dry, small fissures are produced, flexibility reappears, and with it the possibility of flight returns. These observations assist us in comprehending the part which the anterior portion of the wings of the *Phryganidæ* play; which constitute the analogue of the stiff nervure, while the hinder wings represent the flexible membrane. The two wings of an insect thus complement each other.

I shall not further prolong this retrospect. I have limited it to the essential ideas entertained by our predecessors, and to those which will serve us in the future. The preceding experiments, joined to those which you have seen performed under your own eyes, seem to me to establish the following facts, namely: The motions executed by an insect during flight are limited to an elevation and a depression of the wings. It is true that other motions take place in the wings of insects. They are seen to move backward, and in repose to extend parallel to the axis of the body. We also see insects moving their wings backward and forward in preparation for flight. But these motions are not directly

connected with aerial locomotion. The dragon-fly, (*Libellula*,) which propels itself so rapidly, exhibits none of these lateral movements; its wings move exclusively in a vertical plane, as if they turned on a hinge. But we have seen, in the optic method, that the course of the wing in space can be followed by gilding its extremity, and placing it in a ray of sunlight. Now this arrangement furnishes us with a figure of eight, and we further know that during each complete vibration the wing changes its inclination twice. These movements are not controlled directly by the muscles. They are the mechanical effects of the resistance of the air acting alternately on the upper and lower surfaces of the wing in its alternate movements. When the wing leaves the upper limit of its position, it inclines neither to one side nor to the other, its plane being parallel to the length of the animal. But when the impulse of the air is exercised, or as soon as the wing begins to be depressed, the rigid portion, the anterior nervation resists flexure, while the flexible membrane which follows it gives way; drawn down by the nervation which lowers it, elevated by the air which uplifts it, this membrane takes an intermediate position; it inclines about 45°, more or less, according to circumstances. The wing continues its downward motion thus inclined toward the horizon. Thus the reaction of the air, which combines its effect and acts perpendicularly upon the surface which it strikes, can be decomposed into two forces, a vertical and a horizontal force; one serving to elevate, and the second to propel the animal. After this first period the wing membrane will have arrived at the end of its course; the direction of its motion is changed, its action is reversed. A moment of repose, infinitely short, separates these two phases, during which the wing resumes its normal position parallel to the axis of the body. The nervure draws it up again, the air resists as before, and from this conflict results a position between the horizontal and the vertical—an inclination of 45°. This second period contributes as did the first, to locomotion. How remarkable is the simplicity of apparatus by which the desired end is attained!

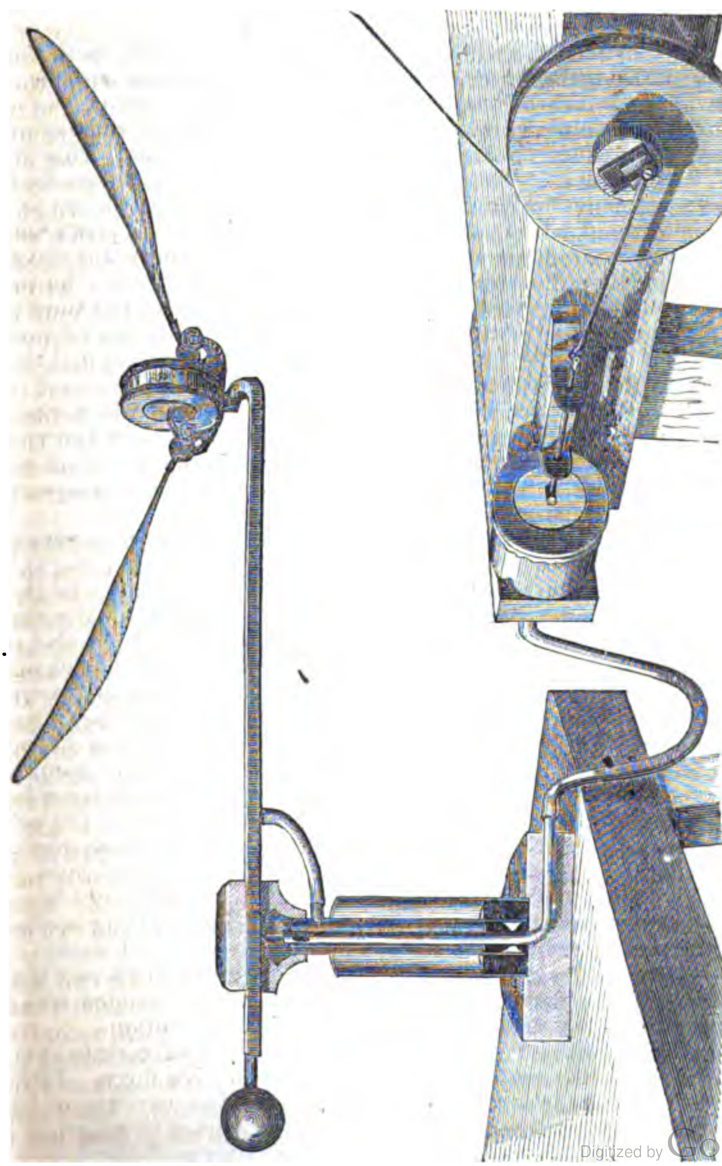
The horizontal force which is generated by the inclination of the plane of the wing is transmitted to the body of the animal and helps to push it forward. But as the body of the insect does not instantaneously take up the motion which is imparted to it, a part of this force is expended in curving the nervure of the wing which, at the same time that it is lowered, is pushed forward. Here is an artificial wing of large size constructed in accordance with the type which we have described; an anterior nervation represented by a stiff rod, with a membrane behind formed of paper pasted upon its edge. Try to strike down an object immediately before you, and you will not succeed. If you strike at an object before you with a downward blow the wing will be resisted by the air, and it will deviate greatly from the point at which you are aiming. From this deviating motion of the wing from the change of plane which it effects, the looped figure which it describes evidently results. It is the combination of these motions which generates the figure of eight previously described. We can now safely say that the two experimental facts are now interpreted by our theory.

A very slight difference has been observed between the two sides of the wing in certain insects; the lower surface is less polished than the upper; it is furnished with rugosities, hairs, or points, which, according to Chabrier, give more hold on the air and reduce the loss of force by sliding. This disposition may contribute to insure the predominance of the useful effect of the lowering over the elevating motion. Furthermore, this predominance of the depressing action of the wing does not exist

in all insects. These find that force as well in the period of elevation of the wing as in the period of its depression, turning almost horizontally the plane in which their wings move. The numerous varieties which the mechanism of flight presents among the species of insects which we have observed will be studied later; they do not conflict with the fundamental principles which I have just announced.

The mechanical conditions which we have just passed in review I have realized in a theoretical apparatus, from which I have obtained the same results as afforded by living insects. This artificial insect is represented by Fig. 8.

Fig. 8.



Representing the artificial insect or scheme of the flight of insects.

An air-pump, moved by a rotary apparatus, alternately compresses and relaxes the air in a tube which traverses the central pivot of the apparatus, where a sort of mercurial gasometer hermetically seals it while permitting the free rotation of the arms. The horizontal branch is hollow, and conducts the air into the apparatus, which is closed by a hollow metallic drum, of which the two circular faces are closed by two sheets of rubber. By the play of the air-pump these two sheets are inflated or contracted both together. They communicate the rapid motions of elevation or depression to the wings by two angular levers. The wings, presenting, like those of an insect, conditions of unequal flexibility, decompose the resistance of the air, and impart to the apparatus a rapid rotary motion around the central pivot.

Imagine two artificial wings, as nearly alike as possible, both inserted on one of these little drums, which I have frequently described. They receive through this drum absolutely synchronous motions of elevation and depression. This apparatus is fixed at the extremity of an arm balanced by a counterpoise, and turning upon a pivot. This arm is hollow, furnishing a canal by which the effect of inflation can be transmitted to the movable drum of the wings. We may consider the drum as representing the body of the insect, and nothing prevents us from really giving it the shape of this animal. The rigid nervures, furnished with flexible membranes disposed to the right and left, will be the two wings, and the animal, instead of being free, will be fixed at the extremity of a movable rod; there is, therefore, only a single motion possible, which is that of turning around the pivot, carrying the attached rod with it. In effect, if I put the air-pump in motion, the artificial insect moves, flaps its wings, and really flies. At each stroke there is a change of plane of the alar membrane; at each stroke the point of the wing describes a figure of eight; and in a general way this theoretical animal, this artificial insect, reproduces all the particulars which the observation of real insects has revealed to us.

This apparatus affords many other advantages besides those of verifying theoretic ideas. It enables us to make new experiments, to which living beings will not lend themselves. We can change one of the conditions, for example the form of the wings, their extent or the rapidity of the stroke, or any other of the circumstances, while all the others remain constant; we may thus discover the influence which each of them singly may have on the mechanism of flight. It is by such experiments that we can assure ourselves of the following fact. In the course traversed by the wing there is only one region useful in the propulsion of the insect; that is the median region. In the two extreme portions the wing has not experienced that change of plane which renders its action effective. Thus we see if we diminish the extent of the motions of the wing, the tractile power produced by the apparatus diminishes considerably, and finally ceases altogether. If the membrane of the wing is too broad, another phenomenon results. The hinder edge of the wing remains almost immovable in space, especially during motions of small amplitude; the nervure only is animated with rapid motion. The air, therefore, is struck by planes inclined inversely to those which act upon it in normal flight, so that the apparatus retrogrades and turns around its pivot in a direction contrary to its usual motion.

Experimental flight also shows the adaptation of certain forms of wings to obtain the most rapid translation of motive force. These are precisely the forms which we find in nature. The nervure of insects does not carry the wing membrane back to its point of insertion. Those parts near the articulation have little vitality; they contribute very little

toward a useful result, embarrassing the neighboring parts, without compensation of any kind. The membrane should not exist except when vitality itself exists in a corresponding degree. Finally, the extent which the alar membrane should have, to best utilize the disposable force, can be determined experimentally. M. de Lucy has compared, in the case of a certain number of animals, the surfaces of the wings to the total weight of the body. He finds an extent of 30 square millimeters in a gnat weighing 3 milligrams; 1,663 square millimeters in a butterfly weighing twenty centigrams; 750 square centimeters in a pigeon weighing 290 grams; 4,506 square centimeters in a stork weighing 2,265 grams; 8,543 square centimeters in an Australian crane, weighing 9,500 grams. But to facilitate the comparison it is necessary to reduce these figures to a common measure; and, in spite of the barbarous phrases to which they lead us, we obtain:

	Square meters.
The kilogram of the gnat represents	10.0
The kilogram of the butterfly represents	8.0
The kilogram of the pigeon represents	2.586
The kilogram of the stork represents	1.988
The kilogram of the Australian crane represents	0.899

The extent of the wings, therefore, is not proportionate to the size of the animal. A wing being given, a maximum rapidity of stroke corresponds to it. To augment the rapidity of the stroke, in hope of indefinitely accelerating the rate of flight, would be illusory; it is possible to accelerate it up to a certain point, but beyond this maximum limit additions become useless. Increasing progressively the action of the air-pump, the strokes of the wings are more rapid, and at first the rapidity of flight will be augmented. Continue the increase, and the rate of flight diminishes. The amplitude of the motion also experiences a considerable reduction, so that at the limit the wings appear motionless, or animated only by a slight quivering. Passing this extreme limit, the apparatus retrogrades. A given wing then corresponds to a fixed rate of progressive strokes; for, by the effect of inertia, the frequency of the strokes is increased only at the expense of their extent, and, when the extent diminished, the propelling force diminishes with it. I leave to yourselves the task of explaining these facts, which are the simple consequences of the principles I have previously explained. I also leave to you the comparison of the mode of progression of insects with the other modes which are seen in other animals or in various mechanical contrivances. You will discover almost everywhere the mechanism of the revolution of forces on the principle of the inclined plane. You will find it in the motion of the tail of a fish, the principal organ of its locomotion; in the sculling motion of a waterman's oar, and even in the screw of a steam propeller.

IV. Flight of birds.

By the simple inspection of a bird's wing it is easily seen that its mechanism for flight is not the same as that of an insect. Let the manner in which the feathers of birds are laid, one over another, be observed, and it will be evident that the air resists the motion of the wing only from below, so that in an inverse direction it finds an easy passage between the long beards of the feathers, which, in this motion, are no longer pressed together. This well-known arrangement, the effect of which Prechlt* has clearly pointed out, has led to the belief

* Untersuchungen über den Flug der Vögel. 8vo. Vienna, 1846.

that to sustain the bird against gravitation the wing needs only to oscillate in a vertical plane, in consequence of the predominance of the resistance of the air acting from below over that acting conversely.

Before discussing the value of this hypothesis, it is necessary to ascertain whether the wing of a bird really oscillates only in a vertical plane. We thus find presented to us, as at the beginning of our studies on the flight of insects, questions which experiment alone can answer. The problem nevertheless presents itself here under definite conditions. From its much larger body than that of the insect, and from our better knowledge of its anatomical conformation, the bird offers to us the means of study and experiment of another description. I shall exhibit, as far as possible, the nature of the muscular force of the bird, and the influence which the particular arrangement of its muscles and the form of its wings exerts upon flight. The methods of myography renders the analysis of the different forms of motion produced by wings so easy that it has been of great assistance in these researches.

Comparative anatomy exhibits the analogue of the anterior limbs of mammals in the bird's wing. Reduced to its skeleton the wing presents, like the human arm, the humerus, the two bones of the fore-arm, and a rudimentary hand in which the metacarpals and phalanges are to be found. The muscles also offer numerous analogies with those of the anterior limbs of man. Among others, some have such an analogy of aspect and function that they can be designated by the same names. In short, in the case of birds, the muscles which attain the greatest development are those which act in extending or flexing the hand on the fore-arm, the fore-arm on the humerus, and, finally, of moving the humerus, that is to say, the whole arm upon the articulation of the shoulder.

Among most birds, especially of the large kinds, the wing appears to remain always extended during flight. So that the *extensor* muscles of the different parts of the wing serve to give that organ the posture necessary for flight, and to maintain it in that position, while the motive work is executed by other and much stronger muscles than the preceding, viz, the pectorals. All the anterior portion of the thorax of birds is occupied by powerful masses of muscle, and above all by a great muscle which, from its being attached to the sternum, the sides, and the humerus, is evidently the analogue of the great pectoral muscle of man and other mammalia. Its office is clearly to draw down the wing quickly and strongly, and to take sufficient hold on the air to sustain as well as to move the whole body of the bird. The middle pectoral is found below the great pectoral; without an analogue in other kinds of animals, this muscle serves to raise up the wing. Lastly, the small pectoral passes externally from the sternum to the humerus; it is an accessory of the great pectoral. It is well known that the strength of a muscle is in proportion to its volume, and as the pectoral muscles of a bird are about one-sixth of its total weight, we readily comprehend that it is upon these powerful organs that the principal duty in the act of flight devolves. Borelli endeavored to deduce from the volume of these muscles the force which the bird employs in flying, and concluded that this equals 10,000 times the weight of the body. I will not stop to refute the error of Borelli, which so many others have called in question, while they endeavored to substitute for the figures of the Italian physiologist estimates which will scarcely be more easy to prove. The great discrepancy which exists between the different estimates of the muscular power of birds shows that the attempts at measurement were premature. If we would make a true estimate to-day of the power

exerted by birds during flight, it would be necessary in the first place to demand from physiological experimentation all the facts of the problem. The estimate in question presupposes an acquaintance with the motions of the wings, with their form, their extent, and their rapidity at each instant; it also supposes a knowledge of the extent of the surface of the wings, their curve, and the angle at which they strike the air. This problem, then, will perhaps be the last which we can hope to solve; but we can study at present, from other points of view, the strength of the muscles of the bird, and estimate some of the characteristics with which it is manifested.

A measure of the maximum effort which the muscles of birds can develop can already be obtained experimentally. This measure may indeed fail to correspond with the efforts developed in flight, but it may prevent us from falling into the exaggeration which would attribute to the muscles of the bird a force superior to the maximum effort of which they are capable.

Of the static force of the muscles of birds.—In physiology the static force developed by a muscle is measured by seeking the maximum weight which this muscle can raise. This determination has been made by Weber,* on the muscles of the frog; by Henke and Knortz,† and since by Koster,‡ on the muscles of man. The maximum weight in these experiments was about one kilogram per square centimeter of muscular section, according to Weber; of five to Henke and Knortz; of seven, according to Koster. If the estimates of Borelli, and even those of Navier, were correct, we ought to find in the muscles of birds a much more considerable static force. On the contrary, it does not appear to me that this force surpasses that of the muscles of the mammalia. I have already shown that the weight of one kilogram, placed on the wing of a pigeon at the articulation of the arm with the fore-arm, cannot be raised by the voluntary efforts of the animal; also, in certain experiments in which we hold a bird immovable, an excellent means of testing the weight consists in putting the bird on its back, the wings extended, and attaching to each wing a bag containing a kilogram of shot.

I wished, however, to have a more precise measure of the strength of the pectoral muscles. For this purpose a hoodwinked harrier was placed on its back in the position just described. The application of the hood plunges these animals into a sort of trance, during which all sorts of operations can be performed on them without their betraying any unpleasant sensation, except by reflex movements. I denuded the great pectoral and the humeral region, tied the artery, and disarticulated the first joint, removing the remainder of the wing. I then fixed a cord to the extremity of the humerus, and at the end of this cord the basin of a balance, into which shot was poured. The body of the bird being perfectly motionless I excited the muscle by inducing interrupted currents of electricity, and while artificial tetanus was produced, an assistant added more shot, until the force of contraction of the muscle was surmounted. At this moment the weight supported was 2 kilograms, 380 grams. Now, the arm of the lever at the end of which this weight had been placed was of the same length as the humerus, that is, about 9 centimeters, the measurement being the length between the attachment of the cord and the center of motion of the humeral articulation. The arm to which the power is applied is evidently much shorter, and is more difficult to measure. In the first place, the attachment of the great

* Wagner's Handwörterbuch der Physiologie.
† Die grosse der absoluten musskelkraft in Heule and Pfeufer, t. XXIV.
‡ Archives neërlandaises, 1866, p. 11.

pectoral muscle extends about 3 centimeters in its longest direction. If we supposed the muscular force applied to the middle of this line of attachment, the leverage of the power would be about 17 millimeters. The weight lifted and the muscular exertion, both multiplied by their respective leverage, are equivalent to each other. It follows that the real value of the power of the bird is $\frac{2380 \times 90}{17}$; which gives $12^{k}.600$ for the entire force of the great pectoral muscle. Dividing this number by 9 ^{cq}, 7, which represents the surface of the section of the muscle, we obtain for each bundle of muscle of the bird, having one square centimeter of sectional surface, a power of 1,298 grams.

The small result which I have obtained may be affected with certain causes of error. In the first place, I had not cut the tendon of the middle pectoral muscle which elevates the wing. It may therefore be objected that, as the electric currents have radiated throughout the deeper regions of the thoracic muscles, and have excited the elevator muscle of the wing of which the action is antagonistic to that of the great pectoral, that is to say, acting in the same direction as the weight, has sensibly diminished the force necessary to neutralize the power of the former muscle. It may also be said that the electric agent cannot produce as powerful an effort in the muscle as that evoked by the will. Admitting that these objections are all well founded, let us double, or even quadruple the force which I have assigned to the muscle, and still we shall not equal the result that Koster attributes to the specific force of the muscle of man. Thus, in spite of the want of precision in the experiments which I have made, I believe the proofs can be found in them that there does not exist in the muscles of birds a notably greater power than that found in those of other animals.

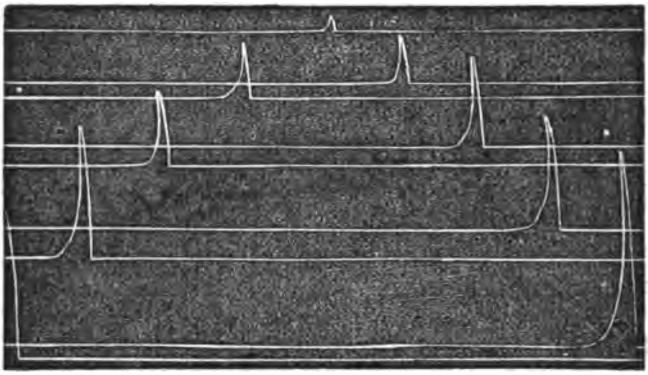
One of the most striking peculiarities of the action of the muscles of birds is the extreme rapidity with which in them is evolved force. Of the different kinds of animals of which I have determined the character of their muscular action, the birds have exhibited the most rapid movements. The curve of motion which a muscle produces can be registered by myography, and thus the duration of its contraction and relaxation can be estimated. If we make use of electricity or any instantaneous motor, on the nerve of a muscle, or on the muscle itself, a motion is evoked of which the duration varies according to the species of animal experimented upon. This motion, which I have called the *muscular shock*, to distinguish it from the prolonged contraction which takes place under other circumstances, lasts in the muscles of the tortoise a second or more; in man it lasts at least six or eight hundredths of a second, and in birds it endures about four-hundredths of a second. This rapidity is an indispensable condition of flight. In fact, the descending wing can only obtain sufficient hold on the air by moving with great speed. The resistance of the air to a plane surface pressing upon it sensibly increases as the square of the velocity with which the plane descends. To have powerful muscles would be of no use to the bird if they acted slowly; their force would be wasted for want of resistance, and no results would be produced. It is otherwise with terrestrial animals which run or gallop over the ground; they definitely utilize their muscular force in work by reason of the great resistance which they encounter. Rapid motion is necessary even to fishes; the water in which they exist resists in proportion to the rapidity with which it is struck by the tail and fins. If the muscular action is quick in the case of fishes, it must be much quicker in that of birds, which move in a much more rarefied medium. To explain the production of such rapid motion as

that exhibited in the motion of birds, it must be admitted that the chemical action which takes place in the substance of the muscle, and which generates heat and motion as in a machine, is produced more rapidly in the muscles of birds than in those of any other class of animals. I must be permitted here to insist on the consideration of the molecular phenomena of which the muscles are the seat, since we shall thus obtain more light upon our subject. Extending to organized beings the principle of the conservation of forces as well as the identity of power and heat, modern physiologists admit that a combustion takes place in the muscles as in the furnace of steam-engines. This combustion or chemical reaction liberates the forces which the separate atoms contain, and renders them evident under two forms, heat and mechanical energy, which are in one sense the complements of each other. Whenever a muscle contracts without raising a weight or otherwise expending power, it becomes sensibly heated. If it raises a weight, or otherwise expends power, it exhibits less heat, and this loss of heat, if it could be measured, would correspond to the mechanical equivalent of the work it has performed. It is true that we cannot estimate exactly the heat that a living muscle disengages during contraction, for the circulation of the blood carries off to different parts of the body more or less of the heat generated. All the experiments of Béclard, Heidenhain, Hien, and others, tend to prove that the production of heat diminishes in proportion to the increase of power expended in work. This is enough to authorize the application of the principle of the conservation of forces to physiology, a principle, moreover, thoroughly justified by human reason. Two methods may be adopted in explaining the production of power from the chemical action which takes place in the muscles. Either the chemical action which we have called combustion liberates force simultaneously in the two forms of heat and power, or, as in the steam-engine, heat is first produced to be afterward partially converted into power. Certain facts render this last hypothesis extremely probable. We can detect, in some cases, in a muscle, the transformation of heat into power. The phenomena are manifested in the following manner: When the muscle of a frog is detached and movements are excited in it by electricity, submitting it, meanwhile, to a gradual increase of temperature, it is seen that the amplitude of the movements produced decrease up to a certain point, and that an instant arrives when the muscle will not react at all. This loss of muscular irritability is produced at about 33° Centigrade. If the muscle is gradually cooled it is seen to resume its irritability. What has taken place? If the motions of the gradually heated muscle be carefully registered side by side with a number of shocks, it is seen that the decrease of their amplitude is due to the fact that the muscle when heated does not return to its normal length after contraction. The minima of the curves are gradually increased, showing that the weight lifted by each shock does not descend again completely. The power exhibited during the contraction of the muscle is not entirely expended by the time the incomplete relaxation follows, and a certain amount of reserved power remains, of which the cause seems to be the permeation of the muscle by heat. And when the muscle, heated above 33°, becomes inert, it is because it has obtained through the action of heat all the contraction of which it is susceptible, that is, it has expended all the power of which it is capable. Figure 9 shows the different phases of this phenomenon.

While the muscle is cooling a contrary result is produced, namely, the subtraction of an amount of heat equivalent to an amount of power expended, that is to say, a relaxation of the muscle and a descent of the

weight which it had raised. India-rubber possesses properties very analogous to those of muscular tissue, in regard to the transformation of heat into power. Take a strip or cord of non-vulcanized rubber and attach to it a weight. It stretches, a negative power is developed, and

Fig. 9.



Showing the effect of heat on muscular contraction. (The figure should be read from right to left.) The first trace caused by the shock is quite high. The second is not so high, but this is partly due to the point from which the tracing starts, being more elevated, as well as the horizontal line from which the mark of the shock extends. This elevation of the point of departure proves that the muscle was in a state of contraction from the influence of heat. The same effect is more and more evident up to the fifth tracing, when the muscle is cooled, and in its return to its original length the tracings of the shocks regain their normal size.

conformably to the mechanical theory of heat you can perceive a notable increase of temperature in the rubber. Conversely, submit the rubber to an increase of temperature, and it will be seen to contract and lift the weight. But under these conditions the amount of power produced by the rubber is very small. It may, however, be rendered greater. About two years ago, Dr. Ranvier gave me an account of the following experiment: He stretched a piece of rubber until it was fifteen or twenty times as long as before, and thus produced in it a passive state, in which it remained elongated even when traction was no longer exerted upon it. While in this state, if the rubber was touched with a warm body, it became considerably thickened at the point of contact by the contraction of the part, and returned to its original length and thickness. Placed in the hollow of the hand the passive thread twisted like a worm, and resumed its normal length and size in a few moments. Part of the phenomena exhibited in the experiment of Dr. Ranvier was readily explained. The heat applied to the rubber was transformed into power by it; but what was the passive state into which the rubber had been brought before the effect above described could have been produced? In repeating the experiment and considering the facts more attentively, I soon perceived that the duration of the traction to which percha was submitted played an important part in the production of the passive state. If I stretched the thread to twenty times its original length and instantly relaxed it, it readily returned to its original condition; but if the contraction was prolonged thirty seconds, a minute, or longer, the thread left to itself contracted only partially. It became partly passive, and much more completely so when the traction was more prolonged. Now, the influence of the duration of the traction can

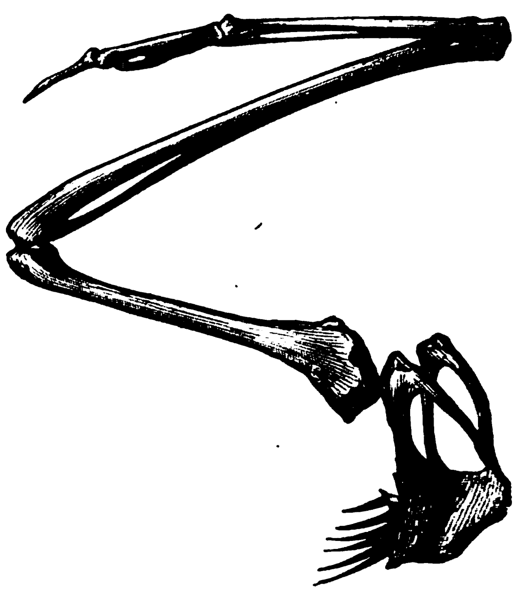
be rationally explained, if we recollect that the rubber becomes heated when stretched. We may then naturally suppose that the heat which appears upon its surface will disappear by degrees if the traction be prolonged; and if heat is necessary for the contraction of the rubber to its original dimensions, it will not contract entirely if a proportion of the heat disengaged in stretching has been dissipated. If this theory be correct, it will be easy to rapidly produce a passive condition of the rubber by quickly depriving it of its sensible heat. This is precisely what takes place. Stretch a thread of rubber, and plunge it into cold water, and it can instantly be taken out in a passive condition, frozen, so to speak, in a state of elongation. Heat it, and it returns to its original dimensions with the development of power. I hardly doubt that the physicist can obtain in the power thus developed the exact equivalent of the heat absorbed.

We have strayed away from our subject, but we shall return to it with enlarged ideas which will enable us to analyze more completely the action of the muscles. In fact, we have in the employment of the percha a sort of *schema* of the muscle. Now you are aware of what assistance can be derived from theoretical apparatus in the study of certain phenomena which are presented with too much complexity, in the case of living beings, to be understood readily. The rubber will assist us to comprehend the manner in which the work of the muscles is performed in animals in general, and especially in the birds with which we are now occupied. Take two cylinders of rubber of the same dimensions and weight, stretch them to ten times their original length, and cool them in that condition. If we restore to these two cylindrical threads the amount of heat which they had lost, both in contracting will perform the same amount of work in a similar manner; that is, both will lift the same weight to the same height. Next, taking two cylinders of the same weight, but of unequal diameter, one, let us suppose, being ten times as thick but only one-tenth as long as the other; stretch each ten times its normal length and cool it; both will still be able to do the same amount of work, but no longer in the same manner. The short, thick cylinder, for instance, will raise a weight of 100 grams a distance of one centimeter. The long, thin cylinder will not support so great a weight at all, but if loaded with a weight of 10 grams will raise it a distance of 10 centimeters. The measure of a mechanical power is obtained by multiplying the weight raised by the height through which it is raised. This product being the same in the two cases, the same amount of power, therefore, has been expended, but not in the same way. So, in the cylinders of rubber which have been stretched in proportion to their length, and from which the same amount of heat has been withdrawn, the amount of power produced by the restitution of this heat will be proportioned to the weight of the rubber; the weight lifted to the diameter of the rubber, and the height to which the weight will be lifted, to the length of the rubber. All that we know of the function of muscle tends to prove that the power exhibited by it is governed by the same laws. Thus, the amount of contraction of muscles depends on the length of their fibers, while the maximum power which they are capable of exerting is proportional to the diameter of the bundle of muscular fibers. For example, in the case of human muscles, the short, thick deltoid muscle is capable of but little contraction, but exerts great force; the long, thin muscles of the forearm, on the contrary, cannot develop the same power, but by their osseous attachments the extent of their contraction is much greater. If we suppose these two muscles to be of the same weight, they can do an

equal amount of work, but in the different ways which pertain to the difference in their structural condition.

If we study the form of the great pectoral muscle, or that whcih produces the downward stroke of the wing in different species of birds, we shall see that this muscle presents much variation in form. In some cases it is long and narrow, in others short and thick. We shall see that this anatomical difference corresponds to important differences in the character of flight. It is enough to observe the flight of a duck and of a marsh harrier to be struck with the great difference in the movements of the wings of these two birds. The duck elevates and depresses its wings very much, describing with each of them an arc of more than 90°. The extent of these movements in the harrier, on the contrary, is very small; when it is observed in profile the point of wing is hardly seen to pass below the shadow of its body. This difference in the type of flight has struck some observers with such force that they have divided the birds into *rowers* and *sailors*. The first are those which strike the air with their wings in flying as a boatman strikes the water with his oar; the second class exposing the surfaces of their wings to the wind like the sails of a ship, fly in a sort of passive condition, utilizing the currents of the air in sustaining and directing themselves. We shall see hereafter that there is a reality in this distinction; at present we shall only accept the incontestable fact that certain species of birds impart a great amplitude to the movements of their wings, while others move them only through a very small extent.

Fig. 10.



Skeleton of the wing and sternum of a frigate-bird. The extreme brevity of the sternum is seen in proportion to the great length of the wing.

I have dissected a wild duck and a harrier to show you the form of the pectoral muscles. In the duck the great pectoral is quite long, while in the harrier it is very short, but the transverse section of the muscle of the harrier is much larger than that of the duck. If we consider only the relative length of the pectoral muscles we see that it varies, as it should do according to the theory; that is, it is greater or less, according to the amplitude of the motion which the bird executes in flying.

But to what does this unequal development in the thickness of the pectorals correspond? It would appear to correspond to a greater muscular exertion in the harrier than in the duck. How can this exertion be demonstrated? If we compare the birds which have short and thick pectorals with those which have long and thin ones, we see that the surface of the wings is very large in the former, while it is very

small in the latter. We know that the resistance of the air against a surface acting with a certain rapidity is in proportion to the extent of that surface; other things being the same, a greater exertion is required to move a large wing than one of less superficial extent. Everything goes to show, then, that the difference in the form of the pectoral muscles in different birds accords with the differences presented in the manner in which they perform their respective work. Two birds of the same weight perform the same labor in flying, and apparently should have muscles of the same weight; but if the muscular masses present the differences in form which we have indicated, we see that the work is done in different ways. The birds with small wings increase the small resistance which these offer to the air by moving them through a large extent of space, while those with large wings equalize the resistance by traversing a shorter distance with them.

Fig. 11.

Skeleton of a flamingo, (after Milne Edwards.) The wing is very large, and the sternum very short.

But, it may be said, nature might have attained these different methods of flight by giving muscles of uniform organization to all birds. It would have been sufficient to have given different positions to the point of attachment of the great pectoral to the humerus, or, in other words, to vary the length of the arm of the lever in proportion to that of the resistance. Comparative anatomy shows that this is not the case. In birds, the great pectoral is always attached close to the articulation of the shoulder. The absolute distance which separates this attachment from the center of motion of the humerus, seems to vary only in accordance with the form of the bird, and not according to the relatively greater or less extent of the wings. This last depends principally upon the length of the forearm and its appendages. It is not necessary to dissect many birds of different kinds to prove the constancy of the law which I

have sought to establish with regard to the relations of the alar surface with the length of the great pectora muscle.

The inspection of the skeleton furnishes the principal elements of this verification. Passing through that part of the zoölogical collection in the museum which is devoted to the exhibition of the skeletons of birds, you will come away convinced of the relation between the extent of the wing and the length of the great pectoral muscle, as shown in the length of the sternum. You see by Figs. 10, 11, and 12, how osteology furnishes the necessary proofs of this statement.

Fig. 12.

Skeleton of a penguin. The wing is very short, and the sternum very long.

In birds the development of the bones of the wing gives us a sufficiently correct idea of the extent of surface presented by these organs when covered with feathers. Compare the prodigious length of the fore-arms in the albatross with those of the duck, guillemot, or diver; the proportion of the bones will give at the first glance the superiority in regard to flight of the albatross in the greater extent of its wings. Comparing the sternum of different birds you will find it large, but very short, in the albatross. On the contrary, in the duck, the diver, and the guillemot, the sternum, though narrower, is comparatively very long. The lateral channels, which lie on each side of its keel, represent, in one sense, a hollow mold of the pectoral muscles. You can thus verify by the skeletons of hawks and other rapacious birds, the fact that short, thick muscles appertain to large wings; and by the skeletons of ducks, swans, and diving birds, that small wings possess more slender but larger muscles. This brings us to the considerations which I have previously brought forward. We now see how we can measure the power developed by a flying bird. It is necessary to know the resistance which the air presents to the surface of its wing, and to multiply this resistance for each stroke by the distance which it traverses. Still the problem is not as simple as one might suppose, after this announcement. All tends to the belief that the rapidity with which the wing strikes the air is not uniform, and that it has increasing and decreasing phases, to which the relative resistance of the air corresponds. To know the exact

nature of the movements of a bird's wing is the question now presented, and this will be the object of our next experiments.

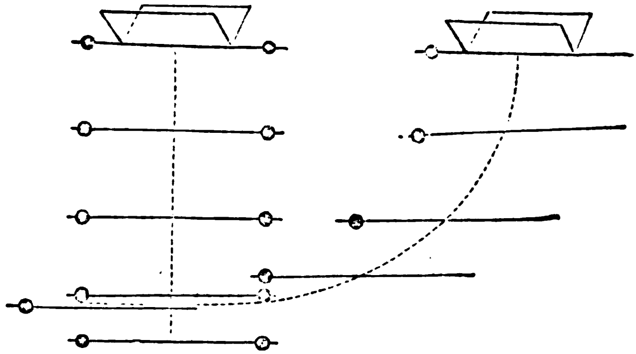
Form of the bird.—All those who have studied the flight of birds have called attention, with great propriety, to the form of these animals, which renders them eminently suited to flight. They have seen in it the conditions necessary for perfect stability in the midst of the air. They have well understood the office of those great surfaces formed by the wings, which sometimes serve as a parachute to enable the animal to descend very slowly, while at others these surfaces glide over the air, following the plane of their inclination, and permitting the bird to descend obliquely, or even to rise, or, as we shall see, to advance with motionless wings. But many observers have gone so far as to assert that some species of birds have an entirely passive flight, and that, submitting their wings to the action of the wind, they obtain a force sufficient to propel themselves in any direction, even against the wind itself. It seems to me important to discuss, in a few words, this essential point in the theory of flight.

The stability of the bird has been fully explained; there is nothing to add to the remarks which have been made on this subject. The attachment of the wings is situated exactly at the most elevated part of the thorax of the bird, and consequently when the extended wings take hold on the air the weight of the body is to be found below this surface of suspension. It is known also that in the body itself the lighter organs, the lungs and air sacs, are above, while the denser mass of the intestines is situated below. Lastly, the thoracic muscles, so heavy and thick, occupy the lowest point of the system, so that the densest portion of the body is placed as much below the point of suspension as possible. The bird which descends with outstretched wings, therefore, always has its ventral region lowest; it does not need to exert itself in order to preserve its equilibrium, but takes this attitude passively, as does the parachute when let fall through the atmosphere, or as the shuttlecock which falls back upon the battledore. But this vertical descent of which I have spoken is exceptional; the descending bird is almost always actuated by a motion previously obtained, so that it slides obliquely upon the air, as does a light body of large superficial extent when placed in the above-mentioned situation. Mr. J. Pline has carefully studied the different kinds of sliding which may occur in this manner, and has even reproduced them by means of a very simple and easily-constructed theoretical apparatus. Take a square sheet of paper and fold it midway, so as to form a rather obtuse angle, as in Fig. 13; then, with a little wax, fix in this angle a small metal rod, furnished with two balls of the same weight, and the result will be an apparatus which will possess stability in the air.

If the center of gravity is exactly in the center of the apparatus, it will be seen to fall vertically when dropped into the air, with the edge of the angle downward. If the center of gravity is displaced by taking away one of the two balls, instead of falling vertically, it will pursue an oblique course and slide over the air with an accelerated motion. The trajectory of the apparatus in this case will be described in a vertical plane if the two sides of the apparatus are perfectly symmetrical; if this is not the case it will be deflected toward the side of least resistance. This effect, easily comprehended, is identical with that produced in the course of a ship by the resistance of the rudder. It can also be produced in a vertical plane, so that the trajectory of the apparatus may present a curve with a superior or inferior concavity, according to the conditions of its projection.

All thin curved bodies tend to slide upon the air in the direction of the radius of their special curve. If we bend the anterior or posterior edge of our little apparatus at a certain point in its oblique course, we shall see it rise, notwithstanding the force of gravity, though its motion soon ceases. What has happened in this case?

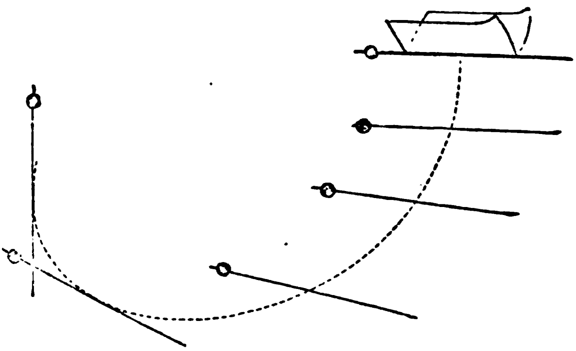
Fig. 13.



Representing to the left Pline's apparatus placed in equilibrium by means of two equal balls at the extremities of the rod which lies at the bottom of the angle of the bent paper. This, as is indicated by the lower representations of the rod, falls vertically. To the right the same apparatus, with only a single ball, is represented. It descends in a parabolic curve, represented by the dotted line.

When there has been but little rapidity in the fall of the object, the curve of its surface remains motionless, because the air offers resistance only in proportion to the rapidity with which they move. Therefore, when this rapidity has been sufficiently great a steering effect is produced, which elevates the anterior extremity of the object and imparts an ascending motion to it. But very soon the weight, which was the motive power of the apparatus, becomes a retarding force, and in proportion as the object ascends its motion becomes slower, and finally ceases. After this, retrogradation begins, to be followed by another rise, and so on, until by successive oscillations the apparatus finally reaches the earth. I may add that if a slight concavity is given to the object below, the reverse takes place, and we see at a certain moment the trajectory sharply deflected downward, and the object strikes the earth with great violence. In the second case, at the moment when the steering effect is produced, the weight is in a favorable position for a precipitate descent, and opposed to the ascending reaction.

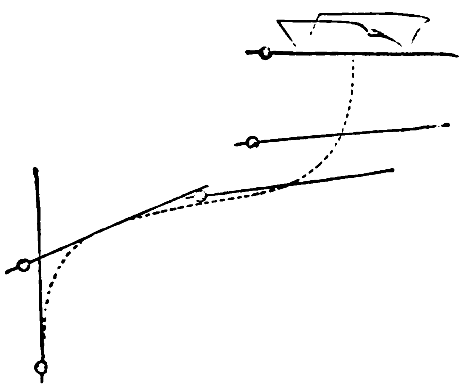
Fig. 14.



The posterior corners of the two planes of the apparatus have been bent upward and inward, so that after a descending curve the apparatus rises, as the dotted line indicates.

I emphasize these effects because they are frequently produced in the flight of birds. The old treatises on falconry describe the interesting evolutions of the birds employed in hunting. Without going back further, we find in Huber (octavo, published at Geneva in 1784) a description of the curvilinear movements of the falcon, to which they gave the name of *passades*, and which consisted in an oblique descent of the bird, followed by a rise in its course. "The bird," says Huber, "when about to strike the earth, carried away by its own rapidity, would be dashed to pieces if it did not call into action a certain faculty which it possesses, stronger than its descending motion, to rise even high enough to make a second swoop. This motion is sufficient, not only to arrest its descent, but even to carry it without effort as high as the elevation from which it came."

Fig. 15.



The posterior corners of the paper have been bent downward. After passing through a parabolic curve the object takes a very rapid descending course.

There is certainly exaggeration in the statement that the bird remounts as high as the elevation from which it descended without further effort. The resistance of the air must overcome part of the force acquired during the descent, and which is transformed into ascending force. We see, however, that the phenomena above described is confirmed by observation, and that it has been considered in some sort as a passive act in which the bird expends no muscular power. The act of hovering in some cases presents a great analogy with the phenomena just described. When some birds, pigeons for instance, have used their wings during a certain distance, the wings are seen to be perfectly quiet during a few seconds gliding through the air, either horizontally or rising or falling. The descending motion has the longest duration; in fact it is only an extremely prolonged descent in which motion is maintained by the force of gravity, which diminishes it in the horizontal or ascending plane. In these latter forms the wing, more or less obliquely directed, takes hold on the air like the toy kite, with this difference, that motion is imparted to this by pulling the string when the air is calm, while the bird utilizes momentum previously acquired by an oblique descent or previous strokes of the wings.

I have already said that observers have admitted that certain birds, which they call sailors, can sustain and direct themselves in the air by means of the wind alone. This theory appears paradoxical. It is incomprehensible that a bird, motionless in the wind, should not yield to the resistance of the air through which it glides. If the *passades* or swoops which the falcon executes can sometimes carry it against the wind, this can only be a transient effect, compensated for by being carried away by the wind more rapidly in another moment. However, this theory has been sustained with great talent by some observers, especially the Count d'Esterno, the author of a remarkable memoir on the flight of birds. "Every one," he says, "can see some birds practicing this method of flight; to deny it is to deny self-evident facts." I myself have noticed this mode of flying, but it has seemed

to me that it is executed in general under the following special conditions: Along the cliffs of the coast of Normandy I have seen the gulls and sea-mews performing their evolutions without moving their wings. I have seen the daws and rooks flying in the same manner around old cathedrals. But the same birds, when they left these special stations, have always appeared to me to use the rowing method of flight; that is to say, making regular strokes of their wings, sometimes interrupted in the daws by swoops of short duration. I then sought to determine the direction of the wind, and this is what seemed to me to occur: When a bird finds itself in the neighborhood of a cliff, where the air is calm or agitated by eddies in a contrary direction to the prevailing wind, it can pass successively from the calm to the agitated air, and conversely. A sea-mew surrendering itself to the force of the wind, receives an impulse which carries it with a certain rapidity, and if, by simply turning, the bird enters a region of calm air, it can utilize the impulse which the wind has given it in returning to the height which it had left. Plunging again into the zone of agitated air, it recommences the evolution which I have just described, without moving its wings, except to give them different inclinations. The daws and rooks appear to me to find the same conditions around the cathedral towers. The authors who have reported the most curious cases of sailing flight have observed them in mountainous regions. It is a condor in the Cordilleras, or an eagle in the Pyrenees. The sailing flight has often been described of certain birds of prey, who, in the middle of a plain, rise and turn without moving their wings. I myself have often seen harriers fly in this manner, but I have always determined, also, that in this case the spiral which they describe is altered by the wind, and that the birds are definitely carried to leeward with a more or less rapid motion.

Even when reduced to these limits the influence of the wind on the flight of birds is very difficult to explain. It is complicated by very different conditions in which the motion acquired by the bird, opposed from various directions by the force of the wind, gives rise to the most varied combinations of motion. It is also known that in the upper regions of the air various currents exist, sometimes even in a contrary direction to those which obtain near the surface of the earth, so that the bird, passing from one to another, find forces which carry it in opposite directions.*

Finally, the question of sailing flight seems to me one of the most difficult to solve. It would be temeritous to absolutely condemn the opinion of observers upon such vague theories and ideas as we possess upon the subject.

One of the most interesting points in the conformation of birds consists in the determination of the relations of the extent of the alar surfaces to the weight of the animal. Is there a constant relation between the weight and these surfaces? This question has been the cause of numerous controversies. It has been already shown that if birds of very different kinds, yet of the same weight, be compared, the wings of some species are found to have four or five times the extent of others. The birds which have large wings are usually those which have been called "sailors," while those which have the wing short and narrow are generally classed as "rowers.' But if we compare two "rowing" birds with two "sailing" birds; if, for still closer comparison, we take them

* The late Mr. Espy suggested that the phenomenon of sailing in the flight of birds is due to upward currents of air which take place in warm weather, or beneath clouds, and especially up the side of a mountain against which the wind is blowing.—J. H.

from the same family, in order that the only differences shall be those of form, a somewhat constant relation will be found between the weight of the bird and the surface of its wings. But the determination of this relation should be based upon certain considerations, which have long escaped the attention of naturalists. Mr. de Lucy sought to measure the surface of the wings and the weight of the body in all flying animals. Now, to establish a common unit among animals of such different kinds and forms, he reduced all the measures to an ideal type, of which the weight should always be one kilogram. Thus, after having proved that the gnat, which weighs three milligrams, possessed wings with a surface thirty millimetres square, he concluded, in the types represented by the gnat, the kilogram of animal was supported by an alar surface of ten square millimeters. By making a comparative table of the measures taken from a great number of animals of different kinds and various forms, he arrived at the following figures:

Species.	Weight.	Wing surface.	Surface per kilogram.
Gnat	3 milligrams	30 sq. millimeters	10 sq. millimeters.
Butterfly	20 centigrams	1,663 sq. millimeters.	8¼ millimeters.
Pigeon	290 grams	750 sq. centigrams	2,586 sq. centimeters.
Stork	2,265 grams	4,506 sq. centimeters.	1,998 sq. centimeters.
Australian crane	9,500 grams	8,543 sq. centimeters.	899 sq. centimeters.

From these measurements, in spite of variations in detail, the evident result is obtained, that animals of large size and great weight sustain themselves with a much smaller proportional alar surface than smaller animals. A similar result already shows that the office of the wing in flight is not merely passive, for a sail or parachute should always have a surface proportioned to the weight which acts upon it; considered, on the contrary, from its true point of view, that is to say, as an instrument for striking the air, the wing of the bird should, as we shall see, present a relatively smaller surface in birds of large size and great weight. The astonishment exhibited at the result of the determinations made by Mr. de Lucy disappeared when it was remembered that there was a geometrical reason why the alar surface could not increase in proportion to the weight of the bird. In fact, if we take two objects of the same shape, two cubes, for example, of which one shall be twice as large in diameter as the other, each one of the faces of the larger cube will be four times as large as the corresponding face of the smaller, while the weight of the greater cube will be eight times that of the lesser one. For all similar geometrically solids, the linear dimensions having a stated relation to each other, the surfaces are as the square and the weight as the cube of their similar linear dimensions. Two birds of similar form, but having, one of them, the spread of the wings from tip to tip twice as great as in the other, will have respective wing surfaces in the proportion of 1 : 4, and weight as 1 : 8. M. P. Demondésir, who applied these principles before me, thought that he had found in them a reason for the smaller size of birds are capable of flight, while those of a larger kind, such as ostriches and cassowarys, do not fly; he observes that if these birds had as large wings as the heron, in proportion to their weight, they could not fold them completely, and would drag them as long and embarrassing appendages. These observations would be correct according to the theory of "sailing" flight, but in "rowing" flight, the amplitude of the

stroke of the wing, increasing in proportion to the size of the bird, multiplies the resistance which the wing meets from the air, and the reaction bears a similar proportion to the weight of the birds themselves. Dr. Hureau de Villeneuve, upon the same principle, has sought to determine the alar extent which would enable a bat of the same weight as a man to fly. He found that each of its wings would be less than three meters in length.

A remarkable work by Hastings* has appeared this year on the relative extent of the wings and the weight of the pectoral muscles in the different species of flying vertebrate animals. The author first shows that among birds the existence can be established of a certain relation between the surface of the wings and the weight of the body. But we should be careful to compare only comparable elements; that is to say, the length of the wings, the square roots of the alar surfaces, and the cube roots of the weight among different birds. Let l be the length of the wing, a its area, and w the weight of the body, we can compare among themselves l, $\sqrt{a}$, $\sqrt[3]{w}$.

Examining different types of bird, Hastings made weights and measurements, from which the following table is extracted:

Species.	Weight.	Surface.	Relation between them.
	w.	a.	$\sqrt{a}\ \sqrt[3]{w} \div \sqrt[3]{w}$.
Larus argentatus	565.0	541	2.82
Anas nyroca	508.0	321	2.26
Fulica atra	495.0	262	2.05
Nettion crecca	275.5	144	1.84
Laus ridibundus	197.0	331	3.13
Machetes pugnax	190.0	164	2.23
Rallus aquaticus	170.5	101	1.81
Turdus pilaris,	103.4	101	2.14
Turdus merula	88.8	106	2.31
Sturnus vulgaris	86.4	85	2.09
Bombycilla garrula	60.0	44	1.69
Alauda arvensis	32.2	75	2.69
Parus major	14.5	31	2.29
Fringilla spinus	10.1	25	2.33
Parus cæruleus	9.1	24	2.34

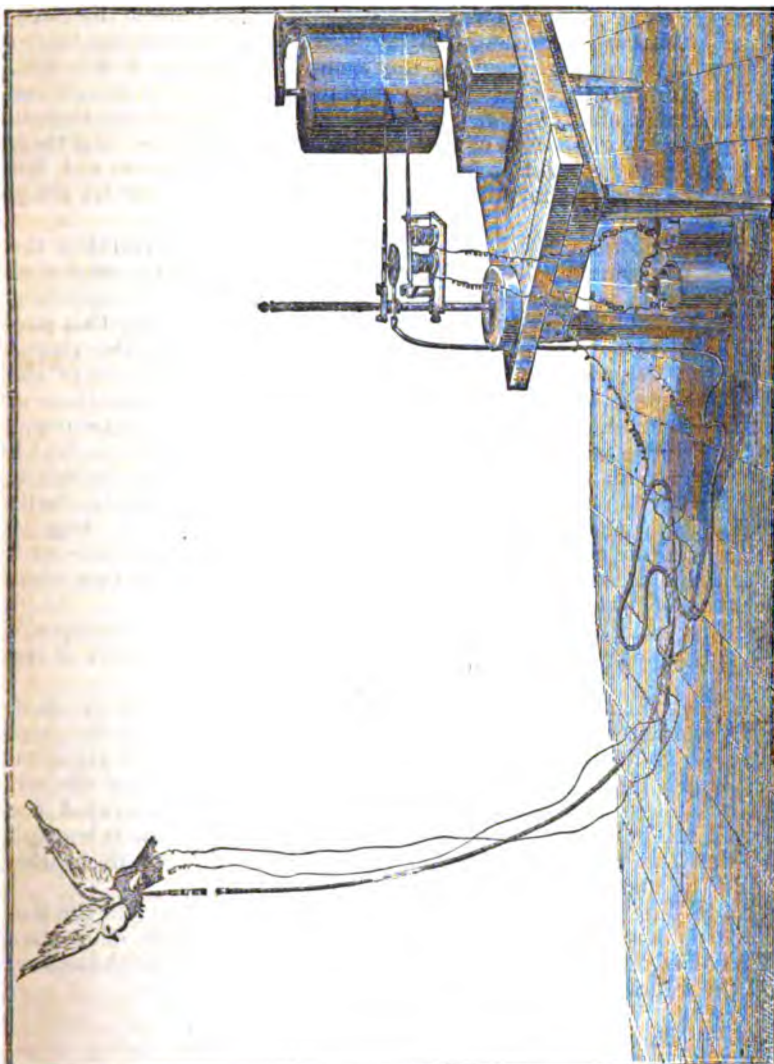
The weight of the pectoral muscles is, on the contrary, in simple proportion to the total weight of the bird, and in spite of the differences which correspond to the different degrees of aptitude to flight with which each species is endowed, we perceive that the proportion of the weight of the pectoral to the total weight is about one-sixth in the greater number of birds.

Each animal capable of sustaining itself in the air must develop a force proportional to its own weight, and should possess an amount of muscle proportioned to this weight; for, as we have seen, if the chemical action which takes place in the wings of birds be always of the same nature, this chemical action and the power which it generates will be proportionate to the size of the muscular masses. Now, how is it that the wings of birds in which the surface varies as the square of the linear dimensions suffice to move bodies of which the variation is in proportion to the cubes of these dimensions? Here it is necessary to

* Archives Neërlandaises, t. iv. 1869.

bring in the theory of power; that is to say, of resistance multiplied by the square of the distance through which it acts in a given time, admitting a uniform rate for the downward stroke of the extremity of the wing in two birds to be compared, and which have the proportion of 1:2 in their linear dimensions. The surface of the wings of the larger

Fig. 16.



Apparatus for registering the motion of the wing of a pigeon by double signals. In one case a small India-rubber tube transmits the record of the muscular action; in the other the periods of elevation and depression of the wing, with their relative durations, are noted by an electric signal.

bird will be, as we have already said, four times as great as that of the smaller one; now, as the resistance of the air against surfaces moving at the same rate is proportionate to their extent, if we call the resistance experienced by the wing of the small bird r, that for the large bird will be $4r$. But these birds, in the downward stroke of their wings, do not execute motions of equal amplitude. In the large bird,

each point of the wing will travel twice as far as the similar part of the smaller bird. If we call the space traversed *g*, the resistance *r*, which the wing of the small bird encounters, we shall have *rg* for the work done by the wing, and 4 *r* 2 *g* or 8 *rg* for the work done by the bird. We see, then, that this work increases in the same proportion as the weight of the animals we are comparing.

Another conclusion results from the preceding considerations. If we admit that the wing possesses the same velocity in both birds, the duration of the stroke will increase with the space traversed by the wing; that is, it will be proportioned to the linear dimensions of the bird. Observation confirms this view by showing that large birds make fewer strokes than small ones do. We have not yet been able to determine exactly the number of strokes of the wings of birds to ascertain if their frequency presents an exact inverse ratio to the size of the animal, but it is easy to see that it is in this manner that the frequency of the wing-strokes of birds varies.

The graphic method, which is easily employed in determining the frequency of the wing-strokes of insects, cannot be similarly employed with birds. It is necessary to adopt some method of transmitting signals from the flying bird to the registering apparatus. For this purpose, I have first used the *electric telegraph*, which furnishes the means of solving the following questions: 1. What is the frequency of the strokes of the wings of a bird? 2. What are the relative durations of the periods of elevation and depression of the wings? The experiment consists in placing at the extremity of the wing an apparatus which breaks or closes an electric circuit at each of the alternate motions, while at the further part of the circuit is placed an electro-magnetic apparatus, which makes a trace upon a turning cylinder. Fig. 16 shows this method of studying the flight of a pigeon, together with another method of transmitting signals. In this figure the two wires are separated from each other.

The writing style traces a crenulated line of which the changes of direction correspond to a change in the direction of the motion of the wing.

In order that the flight may be as free as possible, a fine, flexible cord, containing two wires, establishes the communication between the bird and the writing telegraph. The two ends of the two wires are attached to a very small, light apparatus which, from the resistance of the air, executes a kind of valvular motion. When the wing is elevated the valve opens, the circuit is broken, and the line traced by the telegraph rises. When the wing descends the valve closes; the circuit is also closed, and the line is depressed.

Applied to different kinds of birds, this apparatus registers the frequency of the strokes of the wing in each. The number of species which I have as yet been able to study is very small; I have, however, obtained the following results:

Number of vibrations of the wing per second.

Sparrow	13
Wild duck	9
Pigeon	8
Hen-hawk, *Buteo vulgaris*, a hawk called in England and France the "buzzard" or "*busard*"	5¾
Screech-owl	5
Harrier, *Circus rufus*, marsh harrier of England, *buse* of France	3

The frequency of the strokes varies according as the bird is starting, is in full motion, or at the end of its flight. Some birds, as we know, have periods when the wing is motionless, and when they move by means of the momentum acquired.

It is interesting to observe the relative duration of the periods of ascent and descent of the wings. Contrary to the opinion expressed by some observers, the descending period is generally longer than that of elevation. The inequality of the two periods is especially evident in birds which have large wings and make few strokes. Thus, while the periods are almost equal in the duck, which has very narrow wings, they are unequal in the pigeon, and much more so in the harrier.

The following figures exhibit the results obtained from several species of birds:

Species.	Total distance traversed during one complete oscillation of the wing.	Proportional distance.	
		Ascent.	Descent.
Duck	6.66 centièmes per second	3.0	3.66
Pigeon	7.5 centièmes per second	3.0	4.5
Harrier	21.5 centièmes per second	8.5	13.0

It is more difficult than might be supposed to determine the precise instant of the change of direction in the line traced by the telegraph. The attraction of the magnet and the relaxation have an appreciable duration, if the blackened cylinder turns with sufficient velocity to measure the rapid motions which we seek to analyze. The inflections of the line traced by the telegraph then become curves, of which it is somewhat difficult to determine the precise origin. There is therefore a limit to the precision of the measurements which can be made by the electric method. I think that we cannot approximate by this method nearer than $\frac{1}{200}$ of a second to the duration of a motion.

Another kind of signal allows the estimation of the frequency of the stroke at the same time that it furnishes indications of the successive action of the principal motive muscles of the wing.

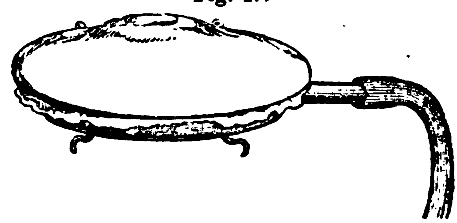
Myographic method.—In 1867 I indicated a myographic method which might be applied without mutilating the animal upon which the experiment was performed. It consists in employing the swelling of a muscle to afford evidence of its changes in length—that is to say, by its contraction or relaxation. Muscles, not being sensibly compressible, cannot change their length without at the same time changing their transverse diameter. A rapid or short, feeble or energetic contraction of a muscle, hence, is accompanied by an increase in diameter, affording the same features of rate or intensity. At each descent of the bird's wing the great pectoral muscle thus exhibits an increase of size, which can be indicated by the registering apparatus.

I have made use of flexible air tubes of India-rubber in transmitting these effects, a method which has enabled me at times to register at some distance the beating of the heart, the pulse, and the motions of respiration.

The bird flies in an inclosure fifteen meters square and eight meters high. The registering apparatus being placed in the center of this enclosure, twelve meters of rubber tubing are enough to establish a constant communication between it and the bird. A sort of corset is applied to a pigeon, (see Fig. 16.) Under this corset, between it and the pectoral

muscle, is placed a little contrivance intended to exhibit the swelling of the muscle. It consists of a small, shallow metal basin containing a spiral spring and is closed over by a thin sheet of rubber. This basin, thus closed, communicates with the transmitting tube.

Fig. 17.



Apparatus for exhibiting the contraction of the thoracic muscles of birds. The upper convex face is formed of a sheet of rubber, held up by a spiral spring, and is applied to the muscles. The lower face, in contact with the corset, carries four little hooks which are caught in the cloth and hold the apparatus in its place.

Any pressure applied to the face of the apparatus depresses the rubber. The air is forced out of the basin and escapes by the tube. If the pressure ceases, the air reënters the basin in consequence of the elasticity of the spring which raises the rubber. An alternate inspiration and aspiration is by this means established in the tube, and the motion of the air transmits to the registering apparatus a signal of the more or less intense pressure which has been exerted upon the rubber cover of the basin. The registering apparatus I have used in all my experiments is also composed of a basin, covered by a rubber membrane communicating with the transmitting tube. The motion imparted to the first basin is transmitted by the air to the rubber cover of the second. The motions of the membrane of the receiving apparatus, amplified by a lever, are written on the smoked cylinder. Figure 16 represents the general arrangement of the experiment in which the electric telegraph and transmission by air are exhibited together. We see the pigeon under experiment furnished with its corset and apparatus for showing the movements of its pectoral muscles. The transmitting air-tube ends at the registering apparatus, which writes on a revolving cylinder. At the extremity of the pigeon's wing is an arrangement which opens or closes an electric circuit as the wing rises or falls. The two wires of the circuit are represented separately, and two cells of Bunsen's battery are seen in their connection, with the helix, which, furnished with a lever, registers the telegraphic signals of the motions of the wings. One precaution is indispensable—the rubber tube which connects the bird and the apparatus must be prevented from stretching. When the bird flies it raises more or less of the tube, and if this is elastic it will become elongated by its own weight, producing a rarefaction of the air contained in the two receptacles, and the registering lever will trace muscular curves on a decending line. To prevent this inconvenience, the tube may be tied here and there to the telegraphic cord by means of ligatures, taking care that the tube is a little longer than the cord, and that it is not subjected to traction. These precautions being taken, nothing prevents the successful transmission of signals. No trouble need be taken in regard to the elasticity of the tube in a transverse direction; its walls are so thick that their elasticity is not brought into play by the feeble changes of pressure to which the air they contain is subjected.

The bird is let loose at one end of the inclosure, the dove-cote in which it is ordinarily kept being placed at the opposite end. The bird naturally flies toward the latter. During its flight the tracings represented by Fig. 18 are obtained.

The trace is seen to differ according to the kind of bird experimented upon. However, in all the traces we perceive the periodical return of two motions, *a* and *b*, which are produced in each vibration of the wing.

Fig. 18.

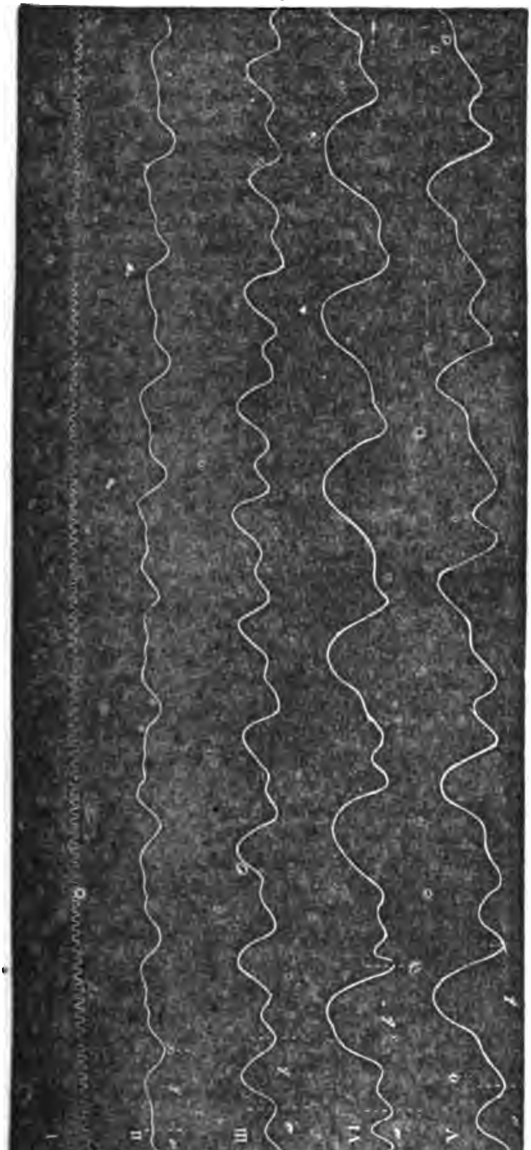


Fig. 19.

Fig. 18. Myographic tracings of the pectorals, obtained from various kinds of birds during flight. I. Tracing of the tuning-fork to be used in measuring the absolute duration of each muscular motion; this tuning-fork vibrates 200 times a second. II. Tracing of the muscles of a pigeon obtained, as in Fig. 16. III. Tracing of a wild duck. IV. Tracing of a hen-hawk. V. Tracing of a harrier.

Fig. 19. Line *a* represents the electric tracing of the ascent and descent of the wing of a harrier, as furnished by the apparatus. Line *b* is a tracing of a tuning-fork vibrating 200 times a second. Line *c*, correction of the electric tracing, which latter does not represent the changes with sufficient abruptness in the figure (*a*) obtained directly from the wing. Line *d*, tracing of the action of the pectoral muscles in the harrier by the air apparatus; *a'*, period of elevation of the wing; *b'*, period of depression. Line *e* will be hereafter referred to; it represents the vertical oscillations of the bird during flight.

What is the signification of these two muscular actions? It is readily seen that the undulation *a* corresponds to the action of the muscle which elevates the wing, and *b* to that of the muscle which depresses it. This can readily be proved by comparing the trace of the muscular action in the electric trace of the elevation and depression of the wing. These two tracings, placed one under the other, show that the period of elevation of the wing agrees with the extent of the undulation *a*, and the period of depression with the undulation *b*.

But to establish this agreement we must take the unequal rapidity of the transmission of the electric and aërial signals into account. We may consider the electric transmission as instantaneous, while the aërial transmission is at the same rate as the rapidity of sound through the air, that is, 334 metres per second. If the points of the two styles are placed vertically one above another, the tracings will not be exactly superposed, but the electric signal will precede the other by a distance corresponding to a certain fraction of a second, according to the length of the tube which has been employed. We can even compute, from the length of the air-tube, the amount of retardation, but it is more certainly ascertained by a special determination for the particular tube which may be in use. In a previous experiment, motions were simultaneously transmitted by the tube and by electricity, and the discrepancy determined. In the apparatus which I am using, the constant discrepancy is .04 of a second. I should therefore set back the electric signals by a corresponding distance, in order that they may agree with the signals transmitted by the air-tube. Fig. 19 shows the superposed tracing from a harrier after correction.

It is easy to understand how the undulations *a* and *b* are produced in all the tracings of the muscles of birds. In fact there exist two distinct planes of muscles, in the upper part of the region investigated, near the end of the sternum. The most superficial is formed by the great pectoral which lowers the wing, the deeper by the median pectoral or elevator of the wing, the tendon of which passes behind the bifurcation of the sternum to attach itself to the head of the humerus. The two supperposed muscles act by their swelling upon the apparatus applied to them. The median pectoral swells when it contracts, signalizing the undulation *a* by its action; the great pectoral signalizes the lowering of the wing in the undulation *b* in a similar manner.

We can verify the correctness of this explanation by a very simple experiment. Anatomy shows us that the median pectoral is narrow, and only covers the inner portion of the great pectoral along the keel of the sternum. So if we displace the little apparatus which reveals the motion of these muscles, and carry it further outward, it will occupy a region where the median pectoral does not cover the great pectoral, and the tracing only presents a simple undulation, which corresponds to *b* in the figures.

It is, therefore, sufficiently demonstrated that the undulations *a* and *b*, in the muscular tracings of the birds upon which I have experimented, correspond exactly to the principal elevating and depressing muscles of the wing; but we cannot attach much importance to the form of these tracings for deducing the precise nature of the motion effected by the muscle. In fact, these motions appear to override one another. So the relaxation of the median pectoral is probably incomplete when the great pectoral commences to act. We should expect no more from these tracings than they naturally furnish, that is to say, the number of vibrations of the wing, the greater or less regularity of its movements, the equality, inequality, and energy of each of them. Restricting the inquiry within

these limits, the experiments show that the strokes of the wings of birds differ in frequency and amplitude in the different moments of flight. At starting the strokes are fewer but more energetic; they attain, after the first two or three, a regular rhythm, which they lose at the moment when the animal is about to alight.

Fig. 20.

Showing the difference in amplitude and frequency in the wing-strokes of a pigeon during a flight of fifteen meters. To the left the extended traces indicate the movements at the commencement of flight. This tracing was recorded on a cylinder which moved very slowly, allowing the record of a large number of strokes to be compressed into a small space.

We shall find in other experiments more complete indications of the variation of the movements of the wing during the different periods of flight.

Such are the certain indications which can be derived from the method of signalizing established between the flying bird and the registering apparatus. But if it is wise to guard our conclusions by more rigorous experiments, it may at least be permitted us to attempt to discover whether the tracings of these muscles cannot furnish us with further information in regard to the motions from which they are derived. I have elsewhere demonstrated that the form of the motion produced by a muscle when it is excited varies according to the resistance which this motion encounters. Thus, in applying the myograph to the muscle of a frog, I have seen that if contraction be impeded by an obstacle the duration of the muscular shock becomes greater on account of that obstacle. Theory, also, would foretell us, that if the muscle presents certain modifications in the different phases of its contraction, the result of unequal resistance overcome at different periods, the swelling of the muscle should also present the same phases. If the tracing is the exact impression of the motions produced by the muscle, it can inform us of the nature of the resistance which the wing of the bird encounters in the different phases of one of its vibrations.

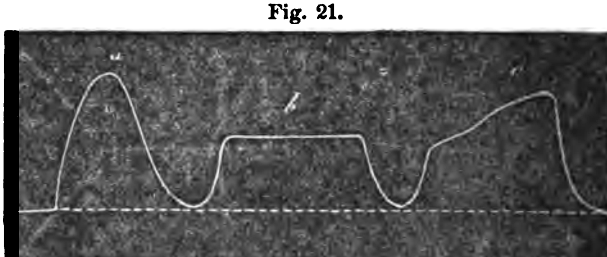
Let us take the most simple example. As the median pectoral and great pectoral are very unequal in size, we may suppose that if the resistance is equal in the two periods of elevation and depression, the duration of the former would much exceed that of the latter; and, as exactly the contrary is the case, we may conclude that the rising wing does not strike the air but cuts it, apparently with its edge, so that the resistance to the elevation is very feeble, and is very strong to the depression of the wing. Now, if we examine the tracing of the depression of the wing we shall find there, within certain limits, the expression of the different amount of resistance which the wing encounters in the different phases of its depression. It is necessary by previous experiments to determine the effect of certain special kinds of resistance, which we may call elastic resistance, in order to better understand the signification of different forms of muscular motion.

Let us take the muscle of a frog, apply it to the myrograph, and excite contraction in it by means of electricity. The form of this contraction varies in the following manner, under the influence of different kinds of resistance opposed to the action of the muscle: If a weight be suspended to the muscle it gives the tracing *a*, Fig. 21. If it encounter an absolute obstacle to all further diminution of length, after a few instants of contraction it gives the trace *b*. Finally, if it encounters an elastic obstacle, as a rubber thread, which presents a surmountable resistance, the muscle gives the curve *c*. It seems as if these different forms were sufficient to characterize the nature of the resistance that the contraction of the muscle has had to overcome.

In the first case it is the inertia of a body; now this body, submitted to the muscular force during a limited period, should have an accelerated motion at first and then a diminishing motion. This is precisely what the form of the curve *a* indicates. In the second case it is not necessary to explain how the horizontal line which forms the summit of the curve *b*, expresses the cessation of all contraction in the presence of an absolute obstacle. Lastly, in the curve *c*, the presence of an obstacle is betrayed by a deflection of the curve; that is, by a change in the rapidity of the motion which produces it; but the contraction does not cease because the obstacle is not insurmountable, but it becomes slower on account of the greater resistance presented.

I have been able to convince myself that in the above-mentioned experiments the swelling of the muscle presents the same phases as its change of length. In fact, I have transmitted to the myograph the motion produced by the swelling of the muscle, and have obtained tracings identical with the preceding. Finally, wishing to know if the apparatus which I have used would faithfully transmit the different phases of the swelling of muscle, I made the following experiment: I applied the little drum which had served to obtain the tracings from the birds (Fig. 18) to my own biceps muscle, fixing it exactly in place by means of a bandage, and put it in communication with the registering apparatus. I then made sudden voluntary motions, as similar as I could make them to each other, but applied to overcome various forms of resistance. In one case I lifted a weight; in another my hand was absolutely arrested in upward motion by being placed beneath a heavy table; in still another I tied my hand to a fixed object with a rubber band which, by a short flexure of my fore-arm, required the utmost efforts of the muscle to stretch it.

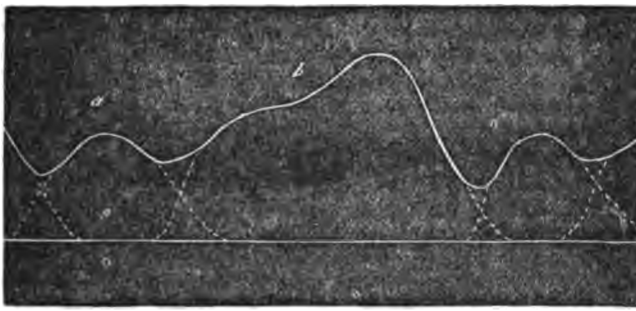
Fig. 21.



Now the tracings which express the swelling of the biceps in these three experiments reproduce the three types represented in Fig. 21, and show very clearly that voluntary exertions had been subjected to different forms of resistance. I tried to force upon the muscles identical motions in each case, which was always a short, vigorous flexure, but the nature of the resistance modified these muscular actions which were intended to be similar to each other, and imparted to them the various phases and durations which are exhibited in the figure. This being settled, let us return to the muscular tracing of the great pectoral of

the bird. I have said that the exact commencement of this motion is undetermined, the elevator of the wing not having fallen into repose before the depressor commences to act, and if we would represent the probable curve of the action of these two muscles from that which the myrograph obtains for us, it will be necessary for us to complete the tracing by means of dotted lines as in Fig. 22.

Fig. 22.



Trace of the action of a harrier during flight: *a*, action of the elevating muscle; *b*, of the depressing muscle. The dotted lines which descend to the axis of the curve complete the probable form of the motions of the two muscles of the wing.

Thus reconstructed, the form of the curves of the elevator and depressor reveals the nature of the resistance which each of these muscles has encountered. The curve *a* of the median pectoral is that of a muscle acting on a weight; it seems to indicate that the inertia of the wing is the only obstacle which the elevator muscle has to overcome. The curve *b* shows us a deflection, during part of which the contraction of the muscle takes a slower motion; it is here that the resistance of the air is interposed. These things happen, then, exactly as in the experiments which I have made upon my own muscles and those of the frog. But you may ask why the deflection of the curve is not produced sooner; and if the depressor muscle can rapidly contract for a certain period before encountering sufficient resistance from the air to impede its motion. This is just what happens; we have the proof of it in the anatomical disposition of the attachments of the great pectoral muscle. We shall see hereafter how the motion of the humerus around its articulation is produced; at present I will only say that in the first part of its action the great pectoral in contracting produces a pivot-like motion of the wing upon the head of the humerus, and that in this first motion the muscle does not experience the resistance of the air which retards its contraction an instant later.

The reader will perhaps consider that an inordinate number of deductions are made from the forms of the curves of the muscles; but those who will familiarize themselves with the use of the registering apparatus, and in particular with the myograph, will soon be convinced that chance does not enter into the formation of the curves, but that the details should find their explanation in the dynamic conditions of the production of muscular power.

Motions executed by the wing of a bird during flight.—We have seen, in regard to the mechanism of the flight of insects, that the fundamental experiment has been that which has shown the trajectory of the point of the wing in each of its evolutions. The knowledge of the mechanism of flight flows, so to speak, naturally from this first idea. The same determination is equally indispensable for the flight of birds, but the optic

method is here inapplicable. The motion of a bird's wing, while too rapid to be followed by the eye, is not sufficiently rapid to form a persistent impression of its entire trajectory upon the retina. The graphic method, which I have hitherto employed, only furnishes impressions of motions which happen to follow a straight line, and it is only by combining this rectilinear movement with the revolving cylinder with a smoked surface that the expression of the rapidity with which the motion is effected at each instant is obtained.

The problem is to find the means of registering on an immovable plane all the motions which the point of a bird's wing makes in space, as if a style had been placed at the end of the wing, and this style traced or rubbed on a piece of paper by its side. It is still further necessary to have a figure of the same nature as the luminous figure of the gilded wing of an insect, that the piece of paper on which the trace is to be made shall remain motionless in regard to the center of motion of the wing of the flying bird, or in effect that it shall follow the bird in all its phases of impulsion through space.

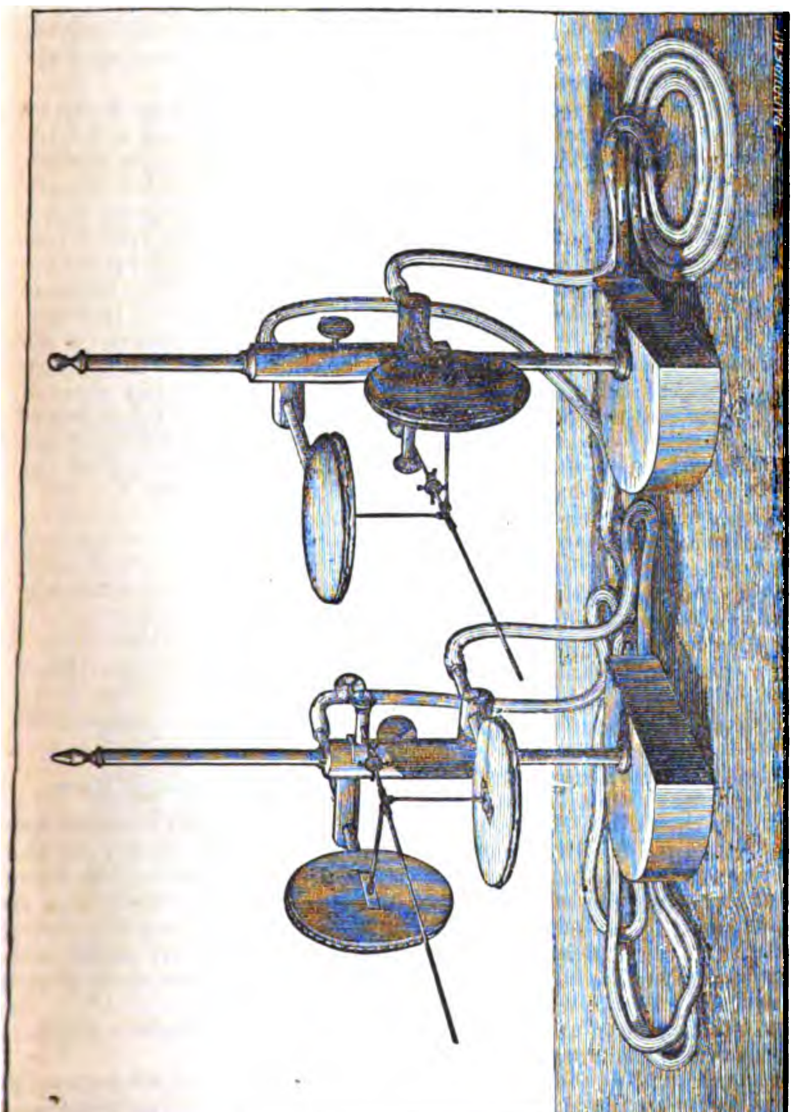
Now, physics teach us that all motion susceptible of registration in one plane can be generated by the rectangular combination of two rectilinear motions. The tracings obtained by Kœnig by arming a vibrating Wheatstone's rod with a style, the luminous figures of musical chords which M. Lissajous has produced by the reflection of a ray of light from two vibrating mirrors perpendicular to one another, are well known examples of the formation of a plane figure by means of two rectilinear movements. Thus, admitting that the motions of elevation and depression of the wing can be transmitted at one time, as well as the back and forward motions of this organ, by supposing that a writing style can simultaneously receive the impulse of these two motions, perpendicular to each other, this point will write on the cylinder the exact figure of the motions of the bird's wing. I tried at first to construct an apparatus which would thus transmit such a motion to a distance and register it, without concerning myself with the way in which I might apply this rather weighty mechanism to the bird.

Fig. 23 represents this provisional apparatus, the description of which is indispensable for the comprehension of the second mechanism, which I shall describe hereafter. Upon two solid feet, carrying vertical supports, are seen two horizontal arms parallel to each other. These are two aluminium levers which, by the transmitting apparatus to be described, should both execute the same motions. Each of these levers is mounted on a ball-and-socket joint, or double articulation, which permits all kinds of motion; thus each lever can be carried above, below, to the right or to the left. It can by its point describe the base of a cone of which the joint will be the apex. In fact, it will execute any kind of motion which the experimentor may choose to impart to it. It is also necessary to establish the transmission of motion from one lever to the other at a distance of ten or fifteen meters. This is done by means of a process with which the reader is already familiar—the use of drums and air tubes.

The lever, which is seen at the left in the figure, is fastened by a metallic arm articulated at one of its extremities to the membrane of a drum placed below it. In the vertical motions of the lever the membrane of the drum rises or falls by turns, producing a throbbing motion of the air in another drum through a long tube, which establishes a communication between them. In the apparatus to the right in the figure, the second drum is placed above the corresponding lever articulated with it, and faithfully transmits all the motions which have been

imparted to the first drum to the left. These movements will be in the same direction in both levers on account of the inversion of the position of the drums. If we depress the first lever it presses down the membrane of the drum below it, inducing a pressure which lifts the membrane of the second drum, and consequently lowers the second lever conversely; the elevation of the first lever produces an influx of air, which raises the membrane of the second lever.

Fig. 23.



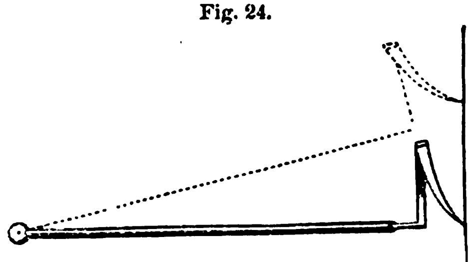
Apparatus intended to transmit to a lever at a distance all the motions executed by another lever around one of its extremities.

Proceeding in the same manner to transmit motions in a horizontal plane, I have placed at the right of one of the levers and at the left of the other a drum with the membrane in a vertical plane, which imparts

lateral motions to these levers. These motions are transmitted by a special air-tube, as before. In the apparatus thus constructed, if we move the end of one of the levers with the finger, the other lever will be seen to execute the same movements with perfect fidelity. The only difference consists in a slight diminution of amplitude. This happens because the air contained in the tubes and drums is slightly compressed, and in consequence does not transmit the whole of the motion which it receives. It is easy to remedy this defect, if it be one, by placing the ball-and-socket joint a little nearer the point whence the motion is transmitted to the second lever. But it is better not to attempt too great amplification, because the friction is thus augmented and the force which should overcome it is diminished.

After having determined that the transmission of such motion can be effected in a satisfactory manner by means of this apparatus, I have sought for the means of tracing these movements upon a plain surface. The difficulty which before presented itself, when I endeavored to apply the graphic method to the study of the wing-strokes of insects, again appeared, but this time there was no means of eluding it, and I contented myself with partial tracings. The point of the second lever described a spherical figure in space which could not be tangent, except as a point, to the smoked surface, which should receive the trace. In consequence, I should have to register the projection of this figure on the plane. Helmholtz had also encountered the same difficulty in the construction of his myograph, and had solved it by causing the point of the writing style to rub continually on the smoked surface by means of a weight. But as I could not attach a weight to the extremity of my lever, I resolved to the following expedient, shown at the end of the lever, in Fig. 24. It is large at the base in order to resist all lateral deviations from friction; this base is fixed on a vertical piece of aluminium which is attached to the extremity of the lever. In this way the point of the contrivance, which performs the office of a style, is situated exactly opposite the end of the lever whose motions it registers. If the lever be elevated and takes the position indicated by the dotted lines in Fig. 24, in traversing this space it has described the arc of a circle, and its extremity will be no longer on the same plane as before, but the elasticity of the contrivance will have carried the point of the style forward, and it will therefore continue to be in contact with the plane upon which it is tracing. Thus the lever elongates or shortens according as the case requires, and its point continually rubs upon the plane. I should add that the surface upon which the tracings are received is of finely polished glass, and that the contrivance which I have used is so delicate that the pressure which it exercises produces scarcely any friction.

Fig. 24.



Elastic point tracing upon smoked glass.

The apparatus being thus constructed, it must be submitted to verification, to ascertain whether the motions are faithfully transmitted and registered. To do this both levers of Fig. 23 are furnished with similar styles, placed against the same smoked glass; and moving one of the levers with the hand, for instance, so as to write my name, the other lever should reproduce the same signature. It frequently hap-

pens that the transmission is not equally good in both directions, which is perceptible by the deformity of the transmitted figure, which is increased more or less in height or breadth. This deficiency can always be corrected, since it is due to the membrane of one of the drums being stretched more than that of the other, and hence yielding less easily to pressure. It is very easy to equalize the tension by tightening the membrane of the other drum until the figure traced by the first lever is identical with that traced by the second.

The modifications by means of which I have rendered this transmission applicable to the study of the motions of the wing of a flying bird, are as follows:

Fig. 25.

Harrier flying with the apparatus, which transmits the motions described by the extremity of its wing.

The apparatus necessarily being heavy, it required a large bird to carry it. Strong adult harriers served for the experiments. I fixed a light strip of wood upon the bird's back, upon which the apparatus was placed, by means of a kind of corset, which left the wings and feet free. That the lever might faithfully execute the same motions as the bird's wing, the joint of the lever should be placed in contact with the humeral articulation of the harrier. As the presence of the drums by the side of the lever does not permit this immediate contact, I had recourse to a parallelogram, which transmitted to the lever of the apparatus the movements of a long arm of which the center of motion was very close to the articulation of the bird's wing. Finally, to obtain an identity of motion between the arm and the harrier's wing, I fixed on the bastard wing, that is to say, on the metacarpal portion of that organ, a well cut screw-vise, furnished with a ring, through which passed the steel arm of which I have just spoken.

Fig. 25 represents the harrier flying with the apparatus in question; below hang the transmitting tubes of the registering apparatus.

After a great many fruitless attempts and changes of construction of the apparatus, which, being very fragile, broke at almost every flight of the bird, I succeeded in obtaining satisfactory results. During flight the registering lever described a kind of ellipse, but I was obliged to give up registering this figure upon a stationary glass. The motions of the wing differing at different moments of flight, the style did not pass over the same points, and I obtained a very confused tracing. I then resolved to use a glass moving horizontally at a uniform rate in order to obtain an extended figure, which I could afterward submit to a geometric correction, and thus obtained as it should be, if traced on a stationary surface, a figure for each instant of flight.

Figure 26 represents one of the numerous tracings which I have thus obtained. The perfect uniformity of these tracings gives me entire confidence in their correctness. To analyze the meaning of this curve, it is necessary to know how the bird flies, how the apparatus is arranged, and in what direction the smoked glass moves while receiving the tracing. The observer being placed opposite the glass, on the smoked side, sees it move from the right to the left; between the glass and himself is a tracing apparatus, with the lever rubbing upon the smoked surface directly in front of him. The bird flying from right to left, in a plane parallel with that of the glass, carries the lever of the apparatus on his right wing, so that the respective levers of the two machines are always parallel to each other. This being known, the tracing should be read from left to right. We have seen that the tracing consists of a kind of ellipse, which the motion of the glass extends into a spiral. The movements, more extended at the beginning of flight, gradually lose a little of their amplitude, and retain a uniform character for some time.

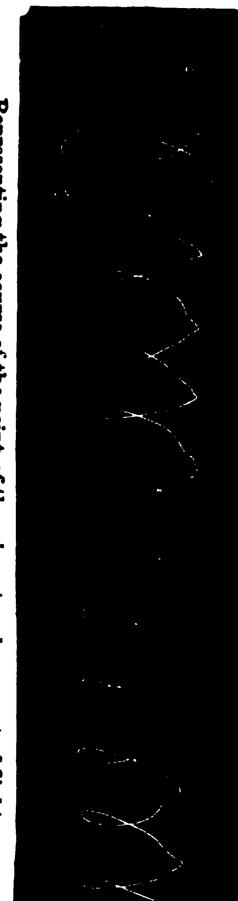


Fig. 26.

Representing the course of the point of the wing at each moment of flight.

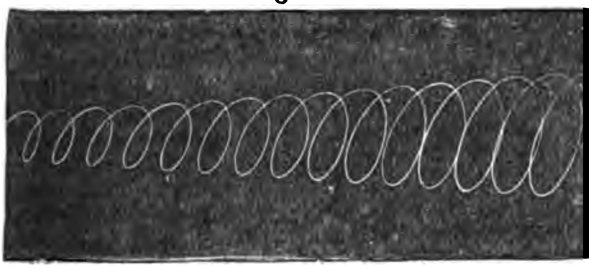
This figure somewhat resembles that which we obtain from a Wheatstone's rod, according to the unison which traces the ellipse which its point describes upon a surface moving from right to left. Fig. 27, showing the tracing of this rod, admits the comparison of the two.

The wing of a harrier thus describes a sort of ellipse, but it is necessary to determine more exactly its shape, and to correct the error caused by the motion of the glass plate.

Such a correction is impossible, unless we know the elevation attained by the wing at the end of successive and equal intervals of time. This once obtained, if we trace parallel horizontal lines representing the position of the wing at each of these successive moments, these lines will cut the descending curve at points which correspond to the successive equal intervals of its course. It is clear that if these successive

points of the curve have been produced at equal intervals of time, each of them, under the influence of the motion of the glass plate, will have a constant deviation toward the right, bearing a stated relation to the preceding point. The correction thus consists in carrying the second point back toward the left twice this amount, the third point three times this amount, and so on. The ascending portion of the curve should also be submitted to this correction, and similarly each part of the tracing. But it is precisely the height which the wing attains in the different ascending and descending motions of its course which we do not know; but this want can be supplied by the apparatus in the following manner:

Fig. 27.



Ellipse traced by a Wheatstone's rod upon a turning cylinder.

Since the principle of this mechanism is founded upon the transmission of two motions, perpendicular to each other, vertical and horizontal, it suffices to suppress the transmission of the horizontal motion to obtain the curve of elevation immediately; that is to say, the expression of the height of the wing at each instant of its course. For this I obstruct the tube of lateral transmission, let the bird fly, and obtain the curve of the heights of the wing at each moment.

The correction being made, and Fig. 26 being selected to show the course of the point of the wing during one of its evolutions, and projected upon a stationary plane, we obtain Fig. 28.

Fig. 28.

Course in space of the extremity of the wing, reduced from the motion of the bird.

The arrows indicate the direction in which the wing moves.

Is this the form characteristic of all birds; or is it only that of the harrier, in the conditions of flight in which it has been placed?

The last supposition appears to be the most probable; we can see, even while comparing the form of the tracing at different instants of its flight while under experiment, that the ellipse is greater and more open in the first strokes of the wing than in the last. It is, however, necessary to except the second stroke of the wing, which has given me a narrower ellipse than any other, in all the experiments which I have made. I do not know to what this special form is to be attributed, but have thought it worth while to mention it on account of its constancy.

Of the rotation of the humerus and the changes of the plane in the wing during flight.—The wing of a bird, like that of an insect, must meet with a sufficient resistance from the air in its motion upward and downward to incline its flexible portion, namely, that which forms the webs and coverts. This cause does produce a change of the plane of the wing, but there is another even more powerful, for it places the wing at the outset of the depressing motion in a favorable position for the double propulsion which is produced. I refer to the pivot motion which the humerus executes around its axis at each contraction of the great pectoral. It is enough to examine the bony crest on which the large tendon

of the great pectoral is inserted, and to consider that this crest is situated on the anterior edge of the humerus, to comprehend that the action of the great pectoral, whose fibers are carried backward and downward, should produce a rotary motion of the humerus around its longitudinal axis. The conformation of the humeral articulation is perfectly adapted to this motion. Finally, the existence of this rotation is rendered still more necessary by the resistance which the air presents to the back of the wing and opposes to the descent of its feathered portion. We can demonstrate the existence of this motion and measure its extent by means of the registering apparatus. But I have thought it best to defer these researches, especially as they necessitate the construction of special apparatus, which would require numerous experiments, and would produce, after all, results of very slight importance. In fact, we are enabled to deduce from the attachment of the muscles the nature of the motion which they produce, and this deduction is especially easy.

I have always sought to verify the existence of this rotary motion of the humerus, and to measure its extent, by the application of electricity to the muscles of the bird. In the experiment for measuring the static power developed by the contraction of the great pectoral muscle, previously described, I noticed that at each excitement of this muscle the humerus executed a rotary motion upon its axis. I fixed in the humerus a rod, perpendicular to its axis, and was enabled, by the angle formed by the two positions of this rod, to demonstrate that the rotation in the harrier corresponded to an angle of thirty-five or forty degrees. It seemed that the limits of this angle were fixed by the attachments of the median and great pectoral muscles. If traction be exerted upon the two antagonistic muscles of a newly dissected bird, it will be seen that the median pectoral raises this member so that its upper face is turned somewhat backward. The action of the great pectoral changes this position of the wing completely, and carries its upper face strongly upward and even a little forward. These expressions, upward and downward, are relative to a plane cutting the bird into a dorsal and a ventral half; but this plane, doubtless, is not entirely parallel with the horizon during flight. But it is certain that the resistance of the air should give a much more pronounced deflection to the feathers during the more rapid descent of the wing.

The most difficult to measure of the influences which change the plane of the bird's wing is that which relates to the pressure of the air on the feathers. Perhaps it may not be impossible to devise an apparatus capable of measuring it, but it so varies with the variations of the velocity with which the wing is lowered, that any measurement which might be obtained would be only the expression of a particular case. It is very probable, on the contrary, that the change of plane due to the action of the pectoral muscles is a much more constant phenomenon. We can infer the action of the two motions of the bird's wing from what has been said of the mechanism of the flight of insects. It is evident that the descent of the wing will have the double effect of raising the bird and of imparting to it a horizontal motion. As to the ascent of the wing, its office cannot be the same, because the imbrication of the feathers does not offer a resistant surface to the air.

Everything tends to show that the ascending wing cuts the air with its anterior edge, but, as we shall see, another phenomenon occurs which uplifts the body of the bird during the elevation of the wing; this is the transformation of the impulse which the bird has acquired during the lowering of the wing. This impulse is changed in rising, by a mechanism analogous to that which raises the toy kite.

In a remarkable study of the flight of birds, M. Liais has been led, through observation and deduction, to adopt this theory, to which the experiments about to be described, I trust, will add new proofs in its favor.

Before leaving the subject, it is necessary to mention the existence of certain other motions in the flight of small birds. I refer to the folding and unfolding of the wings. But the existence of these motions does not seem to be constant, and the eye cannot perceive the least trace of them during the flight of the large birds upon which I have experimented. I shall, therefore, omit the study of these motions, and of their possible effects, and restrict my conclusions on the mechanism of flight to a certain number of determinate species of birds.

The study of the motions of the wings of birds during flight necessarily includes the effect produced by each of these movements. We are tempted to deduce these effects from the nature of the motions which generate them, but it is safer to obtain the solution of this complicated problem from experiment. Two distinct effects are produced during flight: first, the bird is upheld against the force of gravity; second, it is propelled horizontally. Is the bird in the air sustained at a constant elevation, or is it rather subject to oscillations in the vertical plane? Does it not exhibit, by the intermittent effect of the strokes of its wings, a series of ascents and descents, the frequency and extent of which cannot be observed by the eye? Is not the bird also subjected to a variable velocity in its horizontal course? Does it not receive a jerking motion from the action of its wings? These questions can be solved by experiment, in the following manner: Since we possess the means by which distant motions produced by pressure exerted upon a drum filled with air are made to record themselves, we must seek to connect the movements which we would study with a pressure of this kind. The oscillations which the bird executes in the vertical plane should be made to produce alternately strong or feeble pressure on the membrane of the drum, according as the bird rises or falls. The same should be done in seeking the variations of its horizontal velocity. Suppose that a flying bird carries upon its back a light metallic drum, like the one already described; that the membrane of this drum be turned upward, and that this instrument be put in communication with the registering apparatus by means of a long tube. If the membrane of the drum freely partakes of the motions of the bird it will not produce any displacement of the air in the apparatus, and the registering lever will remain motionless. But if we prevent the membrane from partaking of all the motions of the bird, if we can give it a tendency to remain at rest while the drum is moved, motion will be produced in the air with which the drum is filled, and the signals will be registered by the lever. Now, we can produce this tendency to remain at rest upon the membrane by loading it with an inert body, such as a disk of lead.

Fig. 29 shows the drum with an inert mass upon its membrane. This mass is formed of disks of lead, of which a certain number can be added or taken off, until the apparatus responds satisfactorily to the motions of vertical oscillation imparted to it. In this arrangement the movements in the horizontal plane are without influence upon the apparatus. If the drum is suddenly raised, the inert body, not participating in this elevation, depresses the membrane exactly as if the mass itself had been depressed, and the drum had remained motionless. Conversely, when the drum descends, the inertia of the mass resists the motion, as if it or the membrane had been raised and the drum had remained motionless. We may remark that the movement of the lever

is in the same direction as that of the drum; that is to say, if the drum be raised, the lever also raises itself. It may happen, with an apparatus of this kind, that in the motion of the wings rubbing may be produced on the membrane of the drum, which will make confusion in the signals. To avoid this I cover the upper part of the apparatus with a metallic

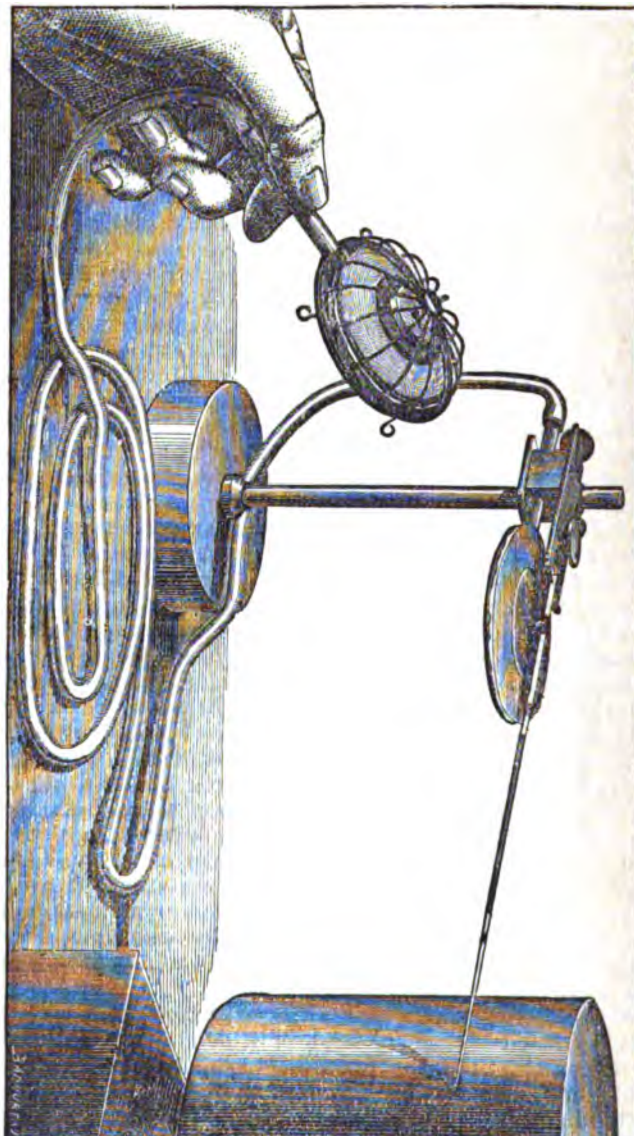


Fig. 29.

Apparatus for transmitting to the registering lever all the oscillations imparted to it in a vertical plane.

network, as seen in Fig. 29. The drum is there represented in the hand, held by the transmitting tube connecting with the registering apparatus. If the drum is moved in the vertical plane, the lever is seen to move in the same direction, at the same instant of time, and with an amplitude proportionate to the motions of the hand. If, on the con-

trary, we give the mass a lateral motion, no effect is produced upon the lever, and no signal is made. But it may be said that an inert mass placed on an elastic membrane tends to execute vibrations peculiar to itself, and that the apparatus will transmit these vibrations of the mass of lead and the membrane which carries it independently of the oscillations of the bird. How shall we get rid of this complication? The law of vibrations teaches us that the duration of the double period of each of them varies with the weight of the vibrating body, and with the elastic force of the lamina which carries it. The greater the mass, and the feebler the elasticity, the longer will be the period of vibration. Now, the motions which we are studying are rather frequent, some birds making eight or ten strokes of the wing per second. If we arrange it so that the period of oscillation of the mass of lead itself is much longer than that of the bird, we shall no longer be troubled by the complication of these interfering motions. By employing a heavier mass and a less tense membrane, a good transmission of motions, which are not too slow, may be obtained, for instance, such as last less than half a second. It is not necessary, either, that the instrument should be applied to the study of the oscillations of all species of birds.

But to make sure of the accuracy of the apparatus it should be verified by the method much like that which I have used to correct all my apparatus. This consists in making, directly by hand, the tracing of the motion which I have imparted to the weighted drum, and observing whether the registered motion was the same as the first.

Experiments made upon different kinds of birds, ducks, harriers, hen-hawks, and owls, have shown me that, in relation to the intensity of the oscillations in the vertical plane, very varied types of flight exist.

Figure 30 shows tracings, furnished by different kinds of birds, upon a cylinder turning at a uniform rate, and contrasted with a tracing produced by a tuning-fork making 100 vibrations per second. These tracings enable us to estimate the absolute and relative duration of the oscillations of flight in these different birds. It follows from these figures that the frequency and amplitude of the vertical oscillations vary a good deal with the kind of bird under consideration.

To better comprehend the cause of these variations, let us register at the same time the vertical oscillations of the bird and the action of the muscles of its wing. If we make this double experiment upon two birds, differing in their manner of flying, such as the wild duck and the harrier, the tracings represented by Fig. 31 will be obtained.

The duck presents two energetic oscillations at each revolution of its wing; the one at *b*, at the moment when the wing relaxes, is easily understood; the other, at *a*, at the moment when the wing rises. To explain the ascension of the bird, during the time of elevation of the wing, it seems to me indispensable to call in the action of the boy's kite, previously alluded to. The bird, moving forward with acquired velocity, presents its wings to the air in an inclined position, similar to that of the kite, and thus transforms its horizontal force into an ascending one.

The flight of the harrier presents the ascension which accompanies the elevation of the wing, in a smaller degree. May not the cause of this difference be recognized as a smaller relative inclination of the wing toward the horizon?

Determination of the different phases of the evolution of the wing, to which the vertical oscillations correspond.—The interpretation of these curves throws light at once upon the experiments made on the variations of the transformation of velocity in the bird, at different moments, during the evolution of the wing.

Fig. 30.

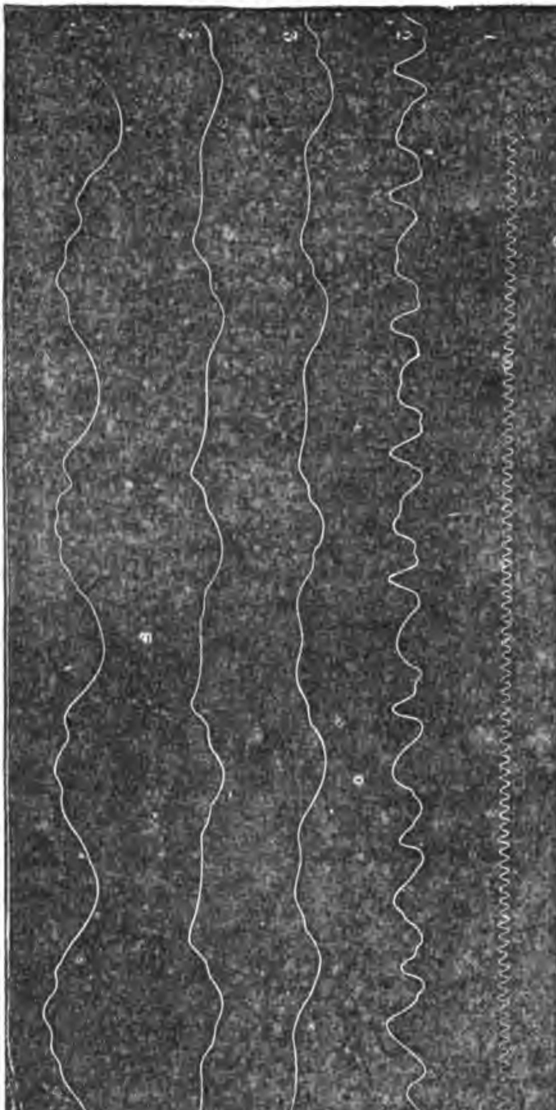


Fig. 32.

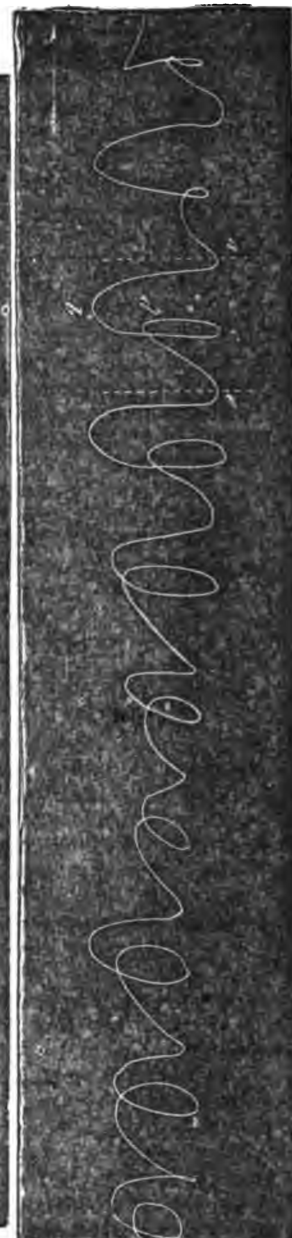
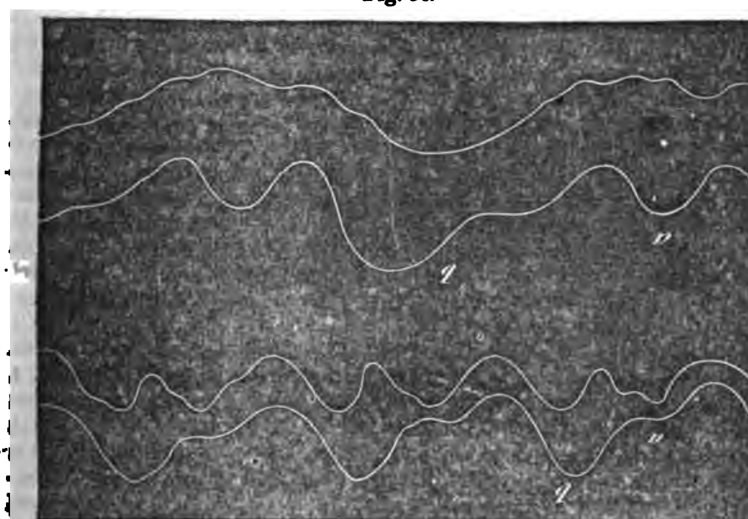


Fig. 30. Line 1. Chronographic trace of a tuning-fork, vibrating 100 times a second; 2. Vertical oscillations of the wild duck during flight. 3. Oscillations of the hen-hawk. 4. Of the screech-owl; and 5, of the harrier.

Fig. 32. Simultaneous tracing of both kinds of oscillations executed by a harrier during flight.

But, before going further, we may remark that the preceding experiment furnishes a very precious lesson in the theory of flight. In fact, if the bird executes a series of ascents and descents, the duration of the descending period will approximately inform us of the amount of the positive work which the bird must perform to rise again to the height from which it fell, and we see that the duck, which makes nine vibrations of the wing per second, executes two vertical oscillations during

Fig. 31.



In the upper half is seen superposed the muscular tracing, and that of the vertical oscillations in a wild duck. Below the undulation *a*, which indicates the elevation of the wing, is seen a vertical oscillation; and another, below *b*, which indicates the lowering of the wing. In the lower portion are the same tracings obtained from a harrier; here the oscillation at *a*, which corresponds to the elevation of the wing, is less marked than in the duck.

each vibration, or eighteen in a second. Each oscillation is composed of a rise and fall, so that each descent of the bird cannot last more than one thirty-sixth of a second. Now, if we substract the effect produced (as in a parachute) by the outspread wings of the bird, we find that a body which falls during one thirty-sixth of a second traverses only fifty-[illegible] millimeters. This fall repeated eighteen times a second constitutes a total rise of 9.36 centimeters, necessary to maintain the bird in the same horizontal plane during one second.

In the tracing of the harrier, the descents are less than in the wild duck, probably on account of the large surface of the wings of this bird.

Determination of the variations of the rapidity of flight.—The second question to be solved relates to the determination of the various phases of rapidity of flight. The solution can be found in the following manner: If the weighted drum be placed upon the bird's back in a vertical plane perpendicular to the direction of flight, it will be insensible to vertical oscillations, and will only indicate those of forward and backward; also, by turning the membrane of the drum forward it is clear that if the advance of the bird is accelerated, the retardation of the weight on the translation of the apparatus will produce a crowding of the air in the second drum, and an elevation of the registering lever, while a relaxation of the effort of the bird will bring about a descent of

the registering lever. Experiments upon the kinds of birds previously mentioned furnish tracings analogous to those of the vertical oscillations. If it is true, as I suppose, that the vertical oscillation of the bird at the moment of raising the wing be due to the upward transformation of velocity, by obtaining, simultaneously, the tracing of the vertical oscillations and those of the variations of velocity, we shall have the means of confirming this theory. When obtaining at one time the two kinds of oscillations in the flight of a harrier, I have seen that the phase of descent of the wing resulted both in the elevation of the bird and the acceleration of its speed. This effect is the necessary consequence of the inclination of the plane of the wing at the moment of its descent, as we have previously shown in the flight of insects. As for the phase of elevation of the wing, it is proved that during the slight ascension which it produces the speed of the bird is diminished. In fact, the curve of the variations of rapidity falls as soon as the bird begins to rise. This is, then, a confirmation of the previously suggested theory of the upward transformation of the speed of birds. Thus by this mechanism the descending stroke of the wing creates the force which produces the two oscillations of the bird in the vertical plane. The downward stroke directly produces the ascent which is synchronous with it, and indirectly by creating the velocity which prepares for the second vertical oscillation.

Simultaneous tracing of the two kinds of oscillation of the bird.—Instead of representing each kind of oscillation separately, I have thought that it would be more instructive to obtain a single line which, by its curves, should represent both of the movements which the body of the bird executes in its course through space. The method which has been used to obtain the curve of the point of the wing, with some modifications can be made to furnish a simultaneous tracing of both kinds of motion. For this both drums must be connected with the same inert mass, and placed at right angles to each other. Turning back to Fig. 23, which shows the two levers connected by tubes which transmit to the one all the motions executed by the other, when any motion is imparted to the first lever, the second lever reproduces the same motion in the same direction. Now, let us charge one of the levers with a mass of lead, and, taking the support of the apparatus in the hand, make it describe some motion in a plane perpendicular to the direction of the lever. We see that the lever No. 2 executes directly opposite movements. In fact, since the motive force which acts on the membranes of the drums is simply the inertia of the mass of lead, and since this mass is always behind the motion given to the apparatus, it is clear that if the whole be raised the mass will keep the lever down; if the whole be lowered, the mass will raise the lever; if it be carried forward, the mass will hold back the lever, &c. Now, the second lever, executing the same motions as the first, will give curves which are directly the opposite of the motion which has been given to the support of the apparatus. This being settled, now for the experiment: For this I take the apparatus represented on the back of the harrier in Fig. 25; I remove the rod which receives the motion of the wing, and the parallelogram which transmits it to the lever. I keep only the lever connected with the two drums and the mounting which attaches it to the bird's back. I fix a mass of lead on this lever and let the animal fly. The tracing obtained is represented by Fig. 32.

The analysis of this curve is at first sight extremely difficult. I hope, however, to succeed in showing its signification. It is traced on the cylinder under the same conditions as Fig. 26, showing the different

motions of the point of the wing. The glass plate moves from the right to the left; the tracing is read from left to right. The head of the bird is toward the left; this flight is in the direction of the arrow. We can divide this figure by vertical lines passing through homologous points, cutting it either at the top of the loops or at the summit of the simple curves, as represented at the points *a* and *e*. Each of these divisions incloses similar elements, although their development is unequal in different parts of the figure. For the present we shall neglect these details.

It is evident that the periodical return of similar forms corresponds to a return of the same phases in an evolution of the bird's wing. The division *a e* thus represents the different motions of the bird during an alar evolution.

Let us recollect that in the curve which we are analyzing all the motions are the reverse of those which the bird really executes. The two vertical oscillations, the great and the small, should then be represented by two downward curves. It is easy to recognize them in the great curve *a b c* and the small curve *c d e*. Thus the bird rises from *a* to *b*, falls from *b* to *c*, again rises from *c* to *d*, and re-descends from *d* to *e*; but these oscillations encroach on each other, producing the loop *c d*. The oscillation *c d e* partly covers the first anteriorly. This is a proof that the indications of the curve are the reverse of the true motion; for, at this moment, the bird recedes, or, at least, relaxes its course. As the apparatus is only sensible of changes of velocity, it is clear that the tracing does not take the uniform rapidity of the bird into account, but indicates acceleration as a forward movement and retardation as a retrograde movement. This figure, then, sums up all the preceding experiments which we have made on the motions of the bird in space. It is here seen that the bird at each evolution of its wings rises and falls twice, successively; that these oscillations are unequal; the larger, as we know, corresponding to the depression of the wing, the smaller to its elevation. It is also seen that the ascent of the bird during the raising of the wings is accompanied by a retardation of its speed, which justifies the theory by which this ascent has been considered as made at the expense of the bird's acquired velocity. But this is not all; this curve also shows us that the motions of the bird are not the same at the beginning and end of flight. We have seen already (Fig. 20) that the first strokes are more extended than the others; we now see that at first—that is, at the left of the figure—the oscillations produced by the descent of the wing are also more extended. But theory foretold that the oscillation of the elevation of the wing being derived from the acquired speed of the bird should be very feeble at the beginning of flight when the animal has acquired but little impetus. The figure shows us that this does happen, and that at the beginning of flight the second oscillation (which forms the loop) is very insignificant.

At last, then, we are in possession of the principal facts upon which the study of the mechanical power developed by the bird during flight can be established, and we see that it is during the descent of the wing that the entire motive force which sustains and directs the bird in space is created.

THE NORTHERN SEAS.

By M. Babinet, *of the Academy of Sciences.*

[*Translated for the Smithsonian Institution.*]

Thanks to modern voyages, particularly since the many and praiseworthy expeditions in search of Sir John Franklin, we have to-day the assurance that the arctic pole is surrounded by a narrow and continuous sea, bounded on one side by the eternally congealed polar space, and on the other by Northern Europe, Siberia, or Northern Asia, and lastly all of America in the higher latitudes. A navigator starting from Dunkirk, on the meridian of Paris, might proceed straight to the pole without encountering land, but stopped by the never melted barrier of ice; if he turned to the right toward the east, he would leave to the left and north Spitzbergen, and to the left and south, North Cape. Passing over the White Sea, he would leave the Polar Sea of Europe at Nova Zembla; then coasting along Siberia, he would come into the somewhat less contracted basin beyond Behring's Strait. Then passing along Northern America, and descending considerably in latitude, he would at last arrive at Lancaster Sound, through which the American Polar Sea empties into the great canal, separating Greenland from the New World. There the navigator would be obliged to descend greatly toward the south, in order to attain the point of Greenland, after having traversed almost the entire polar circle. After passing through Davis Strait he would enter the basin between Europe and America, terminating the northern Atlantic, which has for its limits Labrador, Newfoundland, Great Britain, Norway, the polar circle, Iceland, and lastly Cape Farewell, at the extremity of Greenland. This northern basin of the Atlantic, which communicates at the east and west with the glacial seas, has for companion and analogue the northern part of the Pacific Ocean, enclosed by Kamtchatka, Behring's Strait, Russian and British America. It is not fully determined whether the Pacific sends through Behring's Strait a current of temperate water into the American glacial sea, as the Atlantic does to the glacial sea of the Old World, through the passage separating Cape North from Spitzbergen. As to the existence of a current, following the course we have just described as pursued by the imaginary navigator, compassing the polar regions and moving always to the east, it is an undoubted fact, it seems to me, and at the seasons when the maritime regions traversed by this current are frozen, it nevertheless continues its course under the ice. It should be observed that a similar current flows from the west toward the east, making the circuit of the other pole of the earth; but as the domain of the latter consists entirely of shoreless seas, it follows its course without interruption toward the east, and accomplishes its revolution without change of distance from the pole, its direction unaltered by projections of land, like that of Greenland, which greatly complicate the mechanical circumstances, and modify the course of the two great oceanic rivers (an expression of Homer) which I have added to the five great currents noticed in the admirable work of M. Dupeny of

our institute, and confirmed by the map of M. Findlay, published in England in the Journal of the Royal Geographical Society.

The northern basin of the Atlantic is, as I have just said, entirely analogous to the northern basin of the Pacific. The whale, the seal, the porpoise, and fisheries in general, attract the same European and American navigators. The warm currents, ascending from the equator, produce upon the eastern and western shores of each the same climate and the same vegetation.

Upper California and Oregon rival Western Europe, and when the hardy settlers of the Anglo-Saxon race have peopled the more northern shore of the Pacific basin, it will equal the Norwegian coast, where, according to Horace,

——Ubi Scandia dives
Halecas totum mittit piscosa per orbem.

"Where rich Scandinavia catches herring for the whole world." One of our statesmen has predicted that here will be the seat of civilization in 1957.

M. Arago has often said, quoting Napoleon I, that the most powerful of all rhetorical figures is repetition. I therefore repeat what I have written before, that the superiority of northern climates over those of the south is due to the fact, that almost all the temperate water of the great warm current of the equatorial region ascends to the north, as in the Atlantic, by the Gulf Stream, giving to Norway the rich culture which was the admiration of the observers of La Reine Hortense in 1856, and to Oregon the giants of the vegetable world, trees of 100 metres (330 feet) in height. Look at the map of M. Duperrey, who has discovered one of the three currents which carry the warm water of the equator to the south. Observe those three currents, that of the Indian Ocean, the South Pacific, and Australia; mark the small amount of water carried by them only a short distance from the equator toward the antarctic pole, while the two great and powerful currents of the Atlantic and of the northern Pacific take from the equator even almost the entire mass of water of the warm current encircling the intertropical world, to transport it to latitudes in our hemisphere equal or superior to those of the north of Scotland.

Notwithstanding the contents of many original memoirs upon the question of the excess of temperature of the northern over the southern hemisphere, what a display the world of compilers still make of worn-out lumber, of superannuated opinions, relative to the causes which render our latitudes immensely superior in climate to those of the south. We complain of the inadequacy of literary criticism in our day, but what may not be said of scientific criticism, when we see the finest minds led by the best accredited works, in ignorance of the actual state of science, to repeat the echoes of the meteorological data of 1800!

These preliminary remarks were necessary to show the importance of all investigations made, or to be made, in the northern basin of the Atlantic. The fishers of the Scandinavian shores, and the whaling expeditions to Newfoundland, and the seas separating Greenland from America, follow routes so uniform, and deviate so little from the line leading directly to the scene of their labors, that one is surprised at the incompleteness of the records of their frequent passages. They work for money, not for science; the field is therefore open to more disinterested explorers, and it is astonishing how much more information may be obtained from a single expedition of an intelligent tourist, than from the periodical emigration and return of the seamen of commercial Europe.

The short voyage of Prince Napoleon stands first perhaps in importance for facts collected on our polar seas. Claude has said that not to be born a king is to be a fool. It is at least a great mistake for an explorer not to be a prince. The working force, intellectual and personal, of the great astronomical observatories is spoken of as that of a fall of water or a steam-engine; may we not in a like manner calculate how many facts, observations, drawings, and specimens of all kinds could be collected in a short time by an intelligent leader, with a select corps of seamen and scientists, aided by every desirable means and commanding circumstances, rather than being controlled by them? An immense volume of eight hundred pages in which there is nothing superfluous, scarcely suffices to contain the results of the rapid excursion of 1856. The archeological, descriptive, political and economical parts of the observations find no place in this volume, although they should have been included in its records. If to this already very voluminous record could be added an accurate description of the rich collections brought back by the expedition, a number of curious facts might still be drained from it, and valuable samples given of the harvests ready to be reaped by local collectors or future travelers.

The publication describing the expedition of La Reine Hortense to the northern seas is divided into two distinct parts. The first consists of a rapid and sprightly narration of the events of the voyage from the oil mines of England to the country of Scottish clans; then to Iceland, Jan Mayen and Spitzbergen, to Greenland, the Faroe and Shetland Islands, and lastly to the Scandinavian shores. A distance of twelve thousand miles, accomplished in three or four months, is reviewed by the reader in six hundred pages. Then follow some scientific notices, in small text, which I think may be considered very valuable acquisitions to the knowledge of the globe. The nautical record of M. Du Buisson, and the geological reports of MM. Chancourtois and Ferri-Pisqani, are especially remarkable for the number and interest of the scientific observations they contain. I observe with pleasure that the last mentioned of the three authors named has not fallen short of the estimate I formed of his capacity, as we discussed together the future labors of the expedition, and when he was not yet before the public. With the mention of MM. De La Roncière, Laroche-Poncié, and others who have not contributed to this volume, but whose observations are not less valuable than those of the authors of the scientific notices, it is evident that with a minimum of time the members of this expedition have accomplished a maximum of useful labor. It is a matter of regret that an especial article, among these excellent notices, had not been devoted to the magnetical observations, but they undoubtedly will be published hereafter. It is hardly necessary to say, that I will adhere to these scientific notices in what I am about to say concerning the voyage of La Reine Hortense in the northern seas, and two English publications relative to those regions.

In regard to the currents of the ocean, several facts previously indicated have been confirmed by this expedition, but in a question so complicated and so debated very definite information is required. We see the warm current leave America, pass below Newfoundland, and arrive at Norway, after coasting along the south of Ireland, and passing through the groups of the Faroe and Shetland Islands. This benevolent dispensation of the tropical seas then proceeds northward, and at the latitude of Upper Scandinavia divides into two parts. One half we shall not follow far; it passes into the glacial seas of Europe and Siberia, of which it somewhat modifies the climate. The other ascends, or did ascend two centuries ago, to Spitzbergen, and renders that region habitable by bears,

seals, porpoises, and whales; then this part of the Gulf Stream turns to the left, descends toward Jan Mayen and Iceland, and passes between the latter island and the eastern shore of Greenland. By this return current floating wood is carried from the Gulf of Mexico and stranded upon the northern shore of Iceland; a deserted ship seen twice by the expedition proved its direction and rapidity, which coasting along the eastern shore of Greenland it also brings to Iceland large fields of ice, detached from the belt which renders the island of Jan Mayen inaccessible, and perhaps extends to Spitzbergen. This gloomy bordering of ice, which prevents the mariner from approaching the shore to which it adheres, is called "fast" or land ice, the debris broken off by the waves or by storms forms the field ice; which is generally not very thick, and the salt water of which it is composed loses somewhat of its saline properties in solidifying. The icebergs have an entirely different origin, they are the offspring of the glaciers, and are exclusively formed of fresh water. They are often several hundred feet in height, only about an eighth of which appears above the surface of the water some of them are almost a thousand feet in diameter and are the most formidable moving masses to be found in nature. These flotillas of ice mountains are principally encountered in the arm of the sea separating Greenland from America. They descend with the current which passes through Davis Strait, and are sunk so deeply into the sea that very often they are carried by the current against the wind. It is a singular spectacle to see the berg advance contrary to the superficial current produced by the action of the wind, which the English call the "drift." There is a kind of eddy, formed by the current descending Davis Strait, which eddy or counter-current ascends northward along the west coast of Greenland, and here may be seen many of these floating mountains whirling about. It may readily be conceived that these enormous masses, borne southward by the current, would not melt before reaching the route pursued by the transatlantic steamers between New York and England. They are the terror of captains and passengers. A sailor is constantly on the watch, and at regular intervals calls out to the captain "No icebergs, sir." The loss of many large vessels, which have suddenly disappeared, with no indication of a storm at the time, has been justly attributed to these floating rocks, which no marine chart can record. It is a difficult matter to sail clear of an iceberg in foggy weather. From the observations taken by the expedition of La Reine Hortense, relative to the course of the deserted vessel, which floated round the southern point of Greenland, and was stranded in one of the bays on the west coast of that country, following the eddy formed by the current from Davis Strait, I should judge that M. Duperrey and M. Finlay carry the Gulf Stream too far below Iceland, extending too much the counter-current between that island and Greenland, for according to their charts the disabled vessel descended southward entirely out of the latitudes of the land ice, near which it was first seen.

If you were to open the memoir of Dr. Rink, of Copenhagen, page 145 of the twenty-third volume of the Royal Geographical Society, you would see there represented frozen rivers emptying into the sea, deep valleys filled with ice, like our Alpine glaciers. When these masses of ice, impelled by an irresistible force, which causes them to flow like ductile metal, are no longer sustained by the land and project out into the sea, they break off with a loud noise and thus nature forms her icebergs. One of these fragments, says Dr. Rink, if stranded on the shore would form a mountain over a hundred feet high. The explorers of La Reine Hortense saw some three times the height of Mount Valérien above the

Seine. Imagine that mountain, seen in perspective by the gay promenaders of the Bois de Boulogne, a mass of hard and compact ice, and some faint conception may be formed of these floating giants, which descend Davis Strait toward Newfoundland and the United States. I say this ice is hard and compact. La Reine Hortense tried cannon balls upon some of the impudent little bergs, which paraded before her, without in the least disturbing their promenade. Just as in ghostly legends a spectre, shot through the heart, says coolly to his trembling antagonist "Fire away."

The expedition set the good example of throwing into the sea blocks of wood, with a hole in them, containing a vial with a paper inclosed, on which was recorded the date and the geographical position of the place where the bottle was dropped. Several of these indicators have been picked up and transmitted to the French admiralty, with the date and place of their landing. To test the current flowing toward the east and passing along Siberia, a number of these bottles should be thrown into the strait which, eastward of the White Sea, divides the continent from Nova Zembla, and they will reappear in Behring's Strait, where it has been said whales have been caught still carrying the harpoons with which they had been pierced in the Spitzbergen Seas.

The expedition has proved by unanimous testimony the deterioration of the climate of Greenland, Iceland, and Spitzbergen. In Greenland, at a short distance from the shore, there is now only one immense glacier, like those of the Alps. Mountains and valleys have disappeared under the level of snow and ice, and the astronomers of Mars and Venus, who draw or photograph our planet, must be astonished by this superabundance of arctic snow, which never melts, even when that of Russia, Siberia, and Canada has disappeared in the rays of the summer sun.

The "fast" ice which to-day surrounds the island of Jan Mayen, half way between Iceland and Spitzbergen, renders inaccessible the east coast of Greenland, and sometimes extends to the north coast of Iceland, a circumstance which never happened in former times. Whalers no longer go to Spitzbergen, whose seas are as depopulated as its plains, where the snow has ceased to melt. What is the cause of an effect so disastrous, which threatens at some future time, more or less remote, to drive from Iceland the starving population of about sixty thousand inhabitants, which it feeds to-day, or rather does not feed, since it is by fishing that the Icelanders mostly obtain the insufficient nutriment by which they are barely sustained, even with the assistance of the Danish government? If the *fast* ice should inclose Iceland, as it has the island of Jan Mayen, what would become of the Icelanders?

Hypotheses have not been wanting to explain this deterioration of the climate of Greenland, now buried under a compact mass of ice and snow, fifteen or sixteen hundred feet in depth. It has been generally observed that the shores of the Baltic, of Scandinavia, Iceland, and Greenland, are rising. In one of the bays of the latter country, the expedition found water-worn pebbles at an elevation never attained by the present sea. The ancient banks of the Norwegian shore are in some localities three hundred feet high. It has been supposed that the rising of the bottom of the sea may have arrested the ice descending from the north, and caused the present accumulation between Iceland and Greenland. This hypothesis, I think, is not admissible. The belt of ice bordering Greenland does not, in the least, resemble the masses of ice which the winds and currents sometimes accumulate in the gulfs of the polar seas. I think the true cause of the deterioration of the climate of the

Atlantic polar seas is the diminution of the Gulf Stream, the rising of the bottom of the sea, giving less depth to the bed of the current, tends to lessen it. Formerly the temperate water ascended to Spitzbergen, giving life to the cetacea, birds, and quadrupeds of its rugged peaks, and then descended toward Iceland. This circulation of warm water, I say, being diminished, no longer compensates, as in former times, for a too close proximity to the pole, and the climate of this entire basin has in consequence deteriorated. We may boldly affirm that the current passing around North Cape is lessening, and if it were sounded with a thermometer, as did M. De Laroche-Poncie a few years ago, it would be found to lose every ten years in heat, consequently the shores of the White Sea must undergo a similar decrease of temperature. Nothing has ever been done seriously and in concert to make us acquainted with our world meteorologically. Should an inhabitant of the moon—a Lunite, did any such exist—be transported to us here below, we could tell him the distance from point to point in the moon; the height of its mountains, the form of its craters, the clefts in its soil, the undulation of its plains, the level of its plateaux, the flow of its streams of volcanic lava, and even the effect of the solar heat during its semi-monthly nights and days. But, unhappily, if he wished the inhabitant of the earth—this magician who knew so much about the moon—to enlighten him in regard to physical geography, he would be greatly surprised to hear his learned man respond to almost every question, "I do not know." The Lunite would form a poor opinion of a people who, while confessing the importance, knows so little of the causes of the meteorological changes controlling the fertility and the productions of the soil, upon which depends the material subsistence of the human race.

Le Reine Hortense records this important observation: In 1856 the wind in the latitude of 50° or 60° blew constantly from the east, while in the preceding years the contrary was the case. It was the relapse of the current which caused such great inundations in France in 1856, and the return of the wind to its normal direction restored to the seasons of Europe their natural course. The prediction for 1857 which I drew from these facts was accomplished; but although I boldly announced it in August in an address before a formal session of the five academies, I must confess I am much more confident now than I was then in the acuteness of my conjecture. My confreres, the astrologers, may be encouraged to predict at random. If they make mistakes their blunders will be overlooked, while at a successful guess the world will cry, "a miracle!" In 1846 I foretold a rainy winter, on account of the position of the whales off the bank of Newfoundland. My prediction was verified and highly honored; but when from some other circumstances I made a prophecy concerning the following season, meteorology gave me the lie direct. When to the congratulations upon my sagacity in regard to 1846, I opposed my mistake for 1847, nobody remembered that checkmate. The human mind seems to be such a friend of error, that when it is not individually deceived, it is enchanted if some one will take the trouble to delude it.

As to the question whether the regions under discussion will continue to degenerate, or whether an unfavorable period may not be followed by a favorable one, I answer there is very little hope of the latter; and here are my reasons for such an opinion: In attributing to the rising of the bottom of the Icelandic Sea, the diminution of the warm current by which France and England profit, as they receive a larger share of the temperate water of the Gulf Stream, the question arises whether this rising will cease or continue. Now, it is to be presumed that if the cause

which at the commencement of the present order of nature condemned to sterility Scandinavia, Iceland, Greenland, and the western coast of Europe, still preserves a residue of action; that the effect of such a catastrophe should be very slowly completed, is in accordance with the mechanical law controlling the interaction of flexible bodies—and there are no other in nature. Place a weight upon the end of a spring and the latter will be bent to a certain extent, but leave the weight upon it and still more flexion will be added to the effect already obtained. Notwithstanding assertions to the contrary, I maintain that along the coast of France the continent from century to century is slowly rising, and that the ocean in consequence seems to retire.

The rich collection brought back by Prince Napoleon, and exhibited for several months in the Palais Royal, offers a useful hint to observers in general. The specimens from England, from the Faroe Islands, from Greenland, and even those from Norway, were arranged separately. If a list of the minerals which are found at each place had been added, the representation of each locality would have been complete. The light shed by this short and rapid voyage on every point would, of course, be greatly increased by local observers stationed along the route traced. Science, however, is thankful for any addition, however small, to her acquirements. It is a mathematical axiom, "that there is something more valuable than a thousand pieces of gold—that is, a thousand and one pieces of gold."

The physical constitution of Iceland and of Greenland, in the publication under consideration, is discussed in two short articles from master hands. I see nothing in them to dispute, and I may say, nothing to be added, in spite of the axiom just repeated. Honor be rendered for them to MM. Ferri-Pisani and Chancourtois, both of our polytechnic school. In regard to the ice of Greenland I must remark upon the mournful condition of a land invaded by snow which is perpetual, or which melts only during a very small part of the year. The heat of the sun in summer cannot affect the soil, since its action is absorbed in melting the stratum of frozen water; and in the cold season, on the contrary, the snow and ice decreasing indefinitely in temperature, take away from the soil even the small amount of heat it may have retained. Thus, for example, in the Auvergne Mountains I have found places where the ground was perpetually frozen even when free from snow. The small streams of water just under the soil were at a temperature about zero, and at a certain depth they were even colder. Thus, also, during the constant night of an arctic winter the ice which covers the unfortunate country of Greenland, decreasing constantly in temperature, transmits its coldness to the adjacent soil; whereas in melting under the oblique and feeble rays of the summer sun, its temperature never rises above zero, and the soil therefore receives no heat above zero, while the cold which has been transmitted to it may have been fifty or sixty degrees below that of the melting ice. Surround a thermometer with ice and place it alternately for an hour in a place twenty degrees above and then in a place twenty degrees below zero, and you will find the mean will be below zero. The experiment may be made more conveniently with wax, spermaceti, or a stearine candle, and by the selection of two places, one above and the other below the melting point of the substance employed. If a naked bulb thermometer is used, the two effects will be exactly counterbalanced.

The action of the interior of the earth upon its exterior envelope—a fact fully established by Humboldt—is brought into full light by the geological notices of the voyage. If we add to the igneous fluid, the exist-

ence of which is admitted by all the world, the circumstance indicated by Laplace, namely, that the interior fluid below the lava upon which floats the continents is in a state of an elastic liquid, that it is a kind of compact gas, having for measure of its immense elasticity at the center the weight of half the thickness of the globe, all mechanical difficulties disappear. The erosive action of steam and of gases is admirably treated in these notices of the voyage. As to the supposition formerly entertained, that steam might have raised the beds of continents, this could only have taken place when the thickness of the solidified crust was equivalent in weight to fourteen or fifteen hundred atmospheres; that is to say, to the maximum tension of steam. So that when the solid envelope was more than six kilometres (4 miles) in depth it could no longer be ruptured by the subterranean steam. We now know that this envelope is more than fifty or sixty feet in thickness. I have recently received from the royal astronomer of Scotland, Mr. Piazzi Smith, son of the admiral who has rendered that name so illustrious, a series of admirable photographs of the lava of the peak of Teneriffe. We still seem to see here in these excoriated masses the effect of the corrosive gases driven out by the laboratory of volcanic action, through the fissures formed by the trembling of the earth. In relation to these terrestrial convulsions, produced by chemical action, we involuntarily recall the death of Pliny, suffocated in the dense gaseous eruption of Vesuvius, in the first century of our era.

I leave with regret the picture of the primeval world given in one of the scientific notices. If this excellent article were developed it would make two fine volumes. The technical words, even, are rendered intelligible. It shows us the earth progressing in form in proportion as it cools, and pictures the ulterior forms of things.

Et rerum paulatim sumere formas.

It contains a representation—a very good one, I should think—of the mode of action of the great geyser of Iceland, so closely observed by M. Descloizeaux, which from time to time hurls into the air a column of boiling water equal in diameter to the orifice of the pits of a large mine, and in height to the towers of Notre Dame. Banks and Solander cooked their fish in it. The merry band of Prince Napoleon, sobered no doubt by a ride of several hours on the gallop in the rain, followed by a bivouac in damp clothing, with the exception of a punch made of the boiling water, indulged in none of the eccentricities suggested by solemn British phlegm. Our Frenchmen found at the geyser a tourist, a young Lord Dufferin, with his tent, who had been waiting several days for one of the paroxysms of the volcanic well. It seems the arrival of our travelers decided the geyser; the fountain of boiling water shot up into the air higher than could be measured by the eyes of the spectators, who were stationed too near. The drawing of this beautiful phenomenon embellished the public exhibition in the Palais Royal. "Can it be correct?" asked the visitors, who examined this accurate crayon sketch. In specifying what a geyser is, according to the theory which Captain Ferri-Pisani offers in regard to this volcanic eruption, I cannot do better than compare it to an enormous manoscope of water, above the boiling point, when hurled into the air by the subterranean steam produced by the volcanic fires. Happily it falls directly back into the tube from whence it was momentarily expelled. After this excursion a bill of 220 francs had to be paid for the grass eaten by the hundred horses of the cavalcade. Grass is very rare and very dear in Iceland. But I must confine myself to scientific facts.

In connection with Iceland and the volcanic world, I may as well explain here the formation of Fingal's Cave, of which my readers have probably seen numerous engravings. In this deep grotto, which is entered by a boat, immense basaltic columns rise to the right and left of the explorer to a great height, and support a roof formed of the pendant remains of similar columns. The theory of the formation of this natural curiosity is not more complicated than that of our ordinary caverns. In the latter the primitive disturbance of the locality raised the rocky mass in one unbroken piece, except at the part corresponding to the mouth of the cave. There the stratum of rock disturbed did not follow the part lifted up, and a separation consequently ensued between the portion raised and that remaining in place. This is so evidently the case that traces may be found by close examination of the former juncture of the rock forming the floor of the grotto, and that of its roof; corresponding creases and salient points in each attest their former union. Now suppose the same operation to take place in a locality covered with the beautiful basaltic columns formed by the contraction and solidification of the primeval lava. If while the larger part of the colonnade was elevated, a portion refused to follow the general movement, a cavity would be formed, the upper parts of the immobile columns would form the roof, and the lower parts which retained their original position would constitute the floor of the cave. Caverns of this kind exist in the sides of the basaltic hills, disturbed by the action of the ancient volcanoes of Auvergne. In most cases, as in the cave, or rather the caves of Fingal, for there are several of them, the basaltic rock attained its greatest elevation immediately back of the opening of the grotto, which is consequently higher in front than at the back. Open moderately the long jaws of a hunting dog, and his beautiful teeth above and below will give a very good idea of the divided trunks of the basaltic columns forming the ceiling and pavement of the grotto, while his two fangs, extending from jaw to jaw, represent very well the columns which have remained intact, and support the vault formed by those which have been separated into two parts.

The theory in regard to the fossil wood of Iceland, as given in the exposition of the voyage of La Reine Hortense, appears to me well worthy of confidence, and, as usual, one truth leads to another. If, for example, we admit that this wood was brought to the island by marine currents, the various elevations at which it is found may afford a valuable indication of the rising of the ground. The report of the expedition is silent in regard to the rising of the Faroe Islands. Whenever a good measure is initiated by an expedition it finds continuators, and science is as much benefited by the work induced, as by that actually accomplished. Natural philosophy does not lack encouragement and appreciation, and it pays in renown every attempt to assist its progress. It has been said science has no special public, but the same may be said of the pulpit and the bar.

France ought not to forget that she is the Areopagus of glory. "If I dared," said Frederick the Great in a letter to Maupertuis, on the 12th of March, 1750, "I would say confidently to you Frenchmen what Alexander said to the Athenians: What pains I take to be praised by you!"

It is evident from the nautical report that if La Reine Hortense was not crushed by the ice, it was not the fault of the temerity of the navigators, which was counteracted, it is true, by a most active and judicious supervision. The poor Saxon, which carried supplies of coal, did not escape as well. She suffered from the touch of a very gentle iceberg. Happily she was not utterly destroyed. I congratulate myself

upon having remonstrated with the expedition upon the imprudence of such a cruise along the fast ice, which always produces fog. However, our mariners, more skillful even than imprudent, have returned, and given us a beautiful volume, which does not contain the half of what they could tell us. One thing is to be regretted, that is, the small number of soundings taken. The question of transatlantic communication by means of a submarine telegraph renders very important the determination of the depth of localities where the cable may be laid. The depths measured were generally great.

Another voyage, that of an American, a visit to the people of the north, would deserve more than a simple mention of it by me if science held in it a more prominent place. Mr. Brace's book possesses the rare advantage of being written by a tourist who saw more than the inside of inns. He sought the people *at home*, to borrow a word from the title of his book. It is interesting to view the Scandinavian country through the eyes of a citizen of the United States, and I repeat that the author has brought us more than any other in contact with the people of every grade. "Paris seen in eight days" is the title of the guide-book given to strangers. Could anything be more absurd? Between an excursion to Versailles and an exhibition at the Royal Theater, we receive a visit from an English family, out of health, but with a fearful amount of curiosity to satisfy. After a few words about their overwhelming fatigue, they set out again to see more, if seeing it can be called. An English tourist is reported to have said to a compatriot, on coming out of the picture gallery of the Louvre, "Ah! my friend, what an admirable collection; I have taken an hour to see it, and you know I walk fast." But joking aside, Mr. Brace's work deserves to be translated into French. It possesses all that can be favorably said of a book of travels. The number of those who publish works of this kind is to that of real observers, as the number of true poets is to that of mere verse-makers.

Let us now conclude this review of the voyage of La Reine Hortense. The captain of the vessel, and the officers supporting him, under the direction of the head of the expedition, have given proof of a high degree of genius for arctic exploration. France should not allow such talent to be dormant. We know in what estimation Napoleon the First held lucky men; he considered them especially skillful. Now our mariners were very lucky and also very skillful. Their ability ought to be employed, and that in the line of their specialty. See what a very interesting region remains to be explored.

In entering into the glacial sea on our meridian, but on the other side of the world, which is at noon when we are at midnight, through Behring's Strait, we find, by ascending to the north and west, in the Siberian seas, a basin extending to the islands called New Siberia, which has been but little explored. It is here that from time immemorial the race analogous to the Esquimaux of Europe and America have sought, every winter, the antediluvian ivory which rolls upon our billiard boards, in conjunction with that of the contemporaneous elephants of Asia and Africa. These islands were the catacombs of the primitive animal world. I had hoped that Prince Demidoff, who promised us an expedition by land to Siberia, would have given us the key to this great enigma of nature; but a maritime expedition would be much more efficacious. An especial commission should be sent to Nijney-Kolymsk and the island discovered by Liakof in 1770. Something ought to be added to the knowledge obtained in 1804 of the mammoth preserved intact by the cold. Treasures of organic archæology are hidden in the three or four

islands of the group mentioned. If, according to M. Guizot, seconded by Mr. Airy, France is the pioneer of science, she ought not to be ignorant of what it is in her power to know.

I have not noticed various questions concerning the aurora borealis, terrestrial magnetism, gravity, and physical geography, which this expedition might solve, and I ask pardon for not having given these suggestions as those of MM. Duperrey and Petit-Thouars, whose names would have much more weight than my own; but in the domain of science the sovereign empire is that of truth. One curious fact among the observations of La Reine Hortense I omitted to mention, which is, that in the arctic seas visited the magnetic needle, which here points to the north, turned to the west, or even worse than that. M. Duperrey should be furnished with the means of publishing his magnetic charts, which extend to 1860, and of thereby giving to the twentieth century, now so near, data for which not only that but centuries to come will be grateful.

REPORT ON THE TRANSACTIONS OF THE SOCIETY OF PHYSICS AND OF NATURAL HISTORY OF GENEVA,* FROM JUNE, 1868, TO JUNE, 1869.

By Dr. H. C. Lombard.

[*Translated for the Smithsonian Institution from the memoirs of the society: Geneva,* 1869.]

I am about to perform the last act of the presidency with which my highly respected colleagues have been pleased to honor me, by rendering an account of our transactions and of the changes which have occurred in our society during the academical year which now draws to an end.

Death, that visitor who is almost always unlooked for, has robbed us of several members, emeriti or honorary. In the first category, we recall M. Isaac Macaire, who, after being long one of our members in ordinary, was, at his own request, classed in the number of the emeriti. In the second category, or that of honorary members, we have to record three individuals whose labors have contributed greatly to extend the boundaries of the natural and physical sciences, and whom we had the honor to number among our correspondents. I speak of MM. Von Martius, Matteucci, and Forbes. But if our ranks have sustained some losses, the vacancies thus left have been promptly filled, not, indeed, by savants already numbered, like the honorary members just named, in the first class, with whom our new colleagues would not excuse me for instituting a comparison, but by four members in ordinary, most of them young, and bearing names endeared to us by more than one title. One of these, Professor De La Harpe, already an adjunct of the society under the title of associate, became a member in ordinary in the course of the winter, after having read an original essay on a question of mathematics. Of the three others, who are still of an age which promises a longer career than remains for most of us, one has taken, after several years interval, the place of a colleague regretted by each of us. It is with great satisfaction, therefore, that we have enrolled in our society a second Dr. Jean Louis Prevost, devoted, like his predecessor, to the researches of experimental physiology. The second of our young members, M. Ernest Favre, in taking his place among us, renews the tradition of those geological researches which earned an honored name for his father, Professor Alphonse Favre. Finally, if the last of our young members, M. Edouard Sarasin, has no direct ascendants in the cultivation of the sciences, he numbers warm friends in those pursuits, who will aid him in opening a path of his own in the physico-chemical studies to which he has earnestly devoted himself.

After this summary review of our losses and acquisitions, let us recur to the former and briefly recount the labors of those whom death has removed from us.

M. Isaac François Macaire was born, in 1796, at Geneva, where he fulfilled the customary circle of academic studies. He succeeded his father as pharmaceutist, and availed himself of that circumstance to apply more especially to chemistry and the natural sciences. We need not recall here the obligations of chemistry to the laboratories of phar-

macy; it is sufficient to name Scheele and Sir Humphrey Davy. Our late colleague found, in Pyrame De Candolle, Gaspard De La Rive, and Alexander Marcet, friends and enlightened counsellors, by whom the first steps of his scientific career were greatly facilitated. Received, when very young, as a member of our society, (1821,) he furnished frequent communications, which were printed in the *Annales de Chimie et de Physique* or in the *Bibliothèque Universelle*. His first essays were chiefly directed to the analysis of minerals and to researches in vegetable physiology, in connection with which he gave especial attention to the autumnal coloration of leaves. His inquiry respecting the phosphorescence of the lampyris or glow-worm was widely noticed, as was also a memoir relative to the action of poisons on sensitive plants, which formed a sequel to the analogous researches of M. Franck Marcet. In conjunction with the latter, Macaire conducted many interesting investigations on the composition of organic substances and on certain special questions in chemistry. Named, in 1836, adjunct professor of medical chemistry, he gave at the academy a course of toxicology, as he had previously given courses on applied chemistry, before the Society of Arts, of which he was a member from 1830. He was, in addition, one of the most assiduous collaborators of the *Bibliothèque Universelle*, for which he prepared numerous scientific articles, as well original as bibliographical.

Summoned in the midst of his scientific career to take part in the state councils, he yet found time, notwithstanding his many administrative occupations, to cultivate his favorite science. Isaac Macaire belonged to that generation of savants, daily diminishing in number, who were the first pupils of the distinguished professors by whom Geneva was adorned during the early years of the restoration, and who, consequently, bore a part in the awakening of the scientific movement of that era. The sacred fire then kindled was guarded by him with all that ardor for science which was the predominant characteristic of the period. He loved to recur to those happy times of his youth when the eminent men whom Geneva then possessed diffused an atmosphere of intellectual good-fellowship which it was grateful to breathe.

Of our three honorary members removed by death, the oldest was Dr. Charles Frederic Philippe Von Martius, who was born at Erlangen in 1794, and who became a member of our society in 1821. The name of this celebrated botanist is associated with his great scientific expedition to Brazil and with the publication of numerous and highly esteemed works which have largely extended our knowledge of the flora of the tropical regions. After having traversed the most remote parts of that vast empire and ascended the River Amazon to the frontiers of Peru, M. Von Martius, in company with M. Von Spix, transmitted to Europe the rich collections now deposited in the royal museum of Munich. The premature death of M. Von Spix threw the whole burden of editing and publishing this scientific exposition on M. Von Martius; hence he was obliged to call to his assistance several collaborators and, among others, our fellow-countryman, M. Agassiz, who thus led the way, by the description of the fishes of Brazil, to that more profound knowledge of this immense empire which he has acquired in a more recent expedition; an expedition in which every facility for his studies as a naturalist was placed at his disposal by the liberality of the authorities of the country, no less than by the pecuniary aid of a wealthy citizen of the United States.

But what has earned a distinguished name for Von Martius, besides his analytical genius, his admirable descriptions, his spirit of general-

ization, are three great works, any one of which would have sufficed to confer celebrity as a botanist. The *Nova genera et species plantarum Brasiliensium* forms three volumes in folio, illustrated by three hundred plates executed with great care. The *Historia naturalis palmarum* is also composed of three volumes in folio, embellished with two hundred and forty-five plates, mostly colored, and some of them representing landscapes which show, together with the aspect of certain palms, the part which they fulfil in the vegetation of different countries. Lastly, the *Flora brasiliensis*, a work also in folio, embellished with plates, has reached its sixteenth volume, and will be continued under the care of Dr. Eichler and the auspices of the Brazilian government.

Such are a few of the works of M. Von Martius. It will be understood from this very incomplete enumeration why I felt authorized to say just now that our society was honored by counting so distinguished a botanist in the number of its honorary members. M. Von Martius was permitted to continue his scientific labors to a very advanced age, retaining to the last the vivacity of his mind and that love of study which enabled him to accomplish so many valuable labors. But it has been our privilege to appreciate in the savant the man of kind feelings as well as shrewd observation through the extracts which Professor De Candolle has communicated to us from his letters, in which humor disputes the palm with originality, while he expresses his thoughts sometimes in French, sometimes in Latin; commencing a phrase in one of those languages and finishing it almost without transition in the other.

M. Von Martius breathed his last December 13, 1868, at the age of seventy-five years, encircled with the esteem of his fellow-citizens and the respect of the botanists of all countries.

The career of Carlo Matteucci was shorter, for he died at the age of fifty-seven years, when a long continuance of his scientific and administrative labors seemed still to await him. Devoted, like his predecessors and compatriots, Galvani, Volta, Nobili and Melloni, to the study of electrical phenomena, Matteucci communicated a strong impulse to the science which he cultivated with so much zeal. From the first, the chemical phenomena of voltaic electricity attracted his attention, and he demonstrated, in 1835, that the interior chemical work of the pile is equivalent to its exterior work. He studied successively the propagation of electricity in liquids, whether in a state of continuity or separated into compartments by metallic diaphragms. But it was especially by his researches on animal electricity that the name of Matteucci was rendered illustrious; researches which, first directed to the torpedo and the electrogenous apparatus of that fish, which he discovered to be under the influence of the fourth cerebral lobe, were afterward extended to other electrical animals, resulting in the detection of the curious phenomenon designated by him as *inducted contraction*. These researches in electro-physiology had led M. Matteucci to recognize, not only in electric animals, but in all others, a muscular current whose direction and intensity he made the subject of exact study. Often in conflict, as regards these delicate inquiries, with a German savant, M. Dubois-Raymond, he was under the necessity of greatly varying his experiments in order to arrive at a clearer demonstration of the phenomena which served as a basis for his *Treatise on the electro-physiological phenomena of animals*, published in 1844, and his *Course of electro-physiology*, published in 1857. The death which we are thus called to record is that of an eminent physiologist no less than distinguished physicist. His name was enrolled in our society in 1834, and most of us preserve a lively recollection of his kindliness of manner and of the judicious

remarks with which he accompanied the reading of the memoirs at the sessions in which we had the pleasure of meeting him.

At the mention of Professor James David Forbes we find ourselves in some sort at home, since, besides not a few investigations in pure physics, a great part of the researches of this learned Scotchman had for their object our mighty Alps, with the glaciers which cover their summits and descend into their valleys. It was from no superficial inspection that Forbes described the geology of these mountains and the movement of the glaciers; like de Saussure, upon whose labors he seems to have modeled his own, he has given us his *Travels in the Alps*, founded upon very numerous excursions, as stated by himself in a preface written in 1843: "It was my privilege to receive, in earliest youth, the most vivid impressions from the contemplation of mountain scenery, and I have renewed those impressions in after-life, by traversing the chain of the Alps twenty-seven times by twenty-three different passes, and exploring all the lateral valleys of the great central group of Europe." It was through these multiplied excursions, which were repeated nearly every year since 1843, that Forbes was enabled to deduce his theory of the movement of glaciers, which he compares to a river descending slowly into the valley. But his explorations were not limited to the Alps; they were extended to the volcanic regions, both ancient and recent, of the Gulf of Naples and of Ardèche, as well as to the glaciers and fiords of Norway. Unhappily, the first germs of consumption were developed in his system during these last-mentioned excursions; and it was this disease which conducted him to the tomb, December 31, 1868, at the age of fifty-nine years, after long sufferings, partially alleviated by intervals of comparative good health.

Professor Forbes was a member of our society from the year 1833. He was often present at our sittings, giving us the earliest fruits of the observations which he had just made in the neighboring Alps and communicating them to the public through the medium of the *Bibliothèque Universelle*, as well as the scientific collections of his native country. Some idea of the great intellectual activity of one who died when still in the flower of his age may be formed from the fact that his biographer, M. Reikie, has recorded the titles of one hundred and forty-two works or memoirs which he had published; of these I shall cite but one as specially interesting us, namely, a biographic notice of our colleague, Professor Necker.

After these biographical and administrative details let us pass to the proper labors of our society, and commence with the physical and mathematical sciences.

§ 1.—ASTRONOMY.

Professor Gautier has continued to make the society acquainted with the progress of astronomy, and particularly with that remarkable class of recent investigations to which the employment of the spectral method has given rise. The observations of the eclipse of the 18th of August, 1868, as well as the study of the constitution of the sun, and other celestial bodies, have formed the subject of the greater part of his communications. M. Soret has also occupied our attention with the chemical composition of the solar atmosphere, the exterior strata of which seem to contain only hydrogen and not a multiplicity of gases or vapors, a fact which has been brought forward by certain persons as an objection to the theory by which M. Kirchoff has explained the black stripes

of the spectrum. But if it be admitted that in an assemblage of gases each of them may act singly, it would follow that the atmosphere of hydrogen, by reason of the feeble specific gravity of that gas, must extend much further than those of the other vapors, and form, consequently, the exterior envelope of the sun.

§ 2.—METEOROLOGY.

Professor Gautier read to us an extended notice on the fourth year of the thermometric and pluviometric observations made at the seventy Swiss meteorological stations, and also on some other analogous labors of MM. Wolf, Plantamour, Marguet, Hirsch, Fretz, &c. This notice, forming a sequel to those which M. Gautier had drawn up on the first three years of observation, has been published in the number of the *Archives des sciences physiques et naturelles* for November, 1868.

The meteorology of different regions has formed the subject of some interesting communications. Professor Marcet has related to us his impressions regarding the climate of Egypt, where he had resided for several months. He was especially struck, in ascending the Nile, at the excessive differences which exist between the maxima and minima, according to the hours of the day. In the month of January it was very difficult to support the heat of the sun at 27°, (80° F.,) or even at 22° or 23° (72° or 73° F.) This is referable, doubtless, to the extreme dryness of the air. It scarcely ever rains, in fact, in Upper Egypt and Nubia. The assertion of Herodotus that it had not rained at Thebes since the time of Psammetichus, that is to say during five centuries, is, no doubt, exaggerated, but it is not the less true that rain is extremely rare in those countries. The dragoman of Mr. Marcet had seen rain fall but once in fifteen or sixteen years. The radiation produces an extreme coldness at the rising of the sun. It appears that at Ismaila, where many plantations have been formed since labor was commenced on the canal of Suez, it rains more frequently than of old. In higher Egypt and Nubia the sky is almost always clear. M. Marcet observed clouds, but he believes that it was a misty appearance produced by the *Kamsin.*

A summary of meteorological observations made at Hayti during five years was communicated to us by Professor Gautier; the extremes of temperature observed in that space of time were 13°, 5°, and 38°, (56°, 41°, and 100° F.) M. Gautier has received the commencement of observations made, at his instance, on the coast of Labrador by the Moravian missionaries, to whom he had sent thermometers prepared and regulated at Geneva.

Professor Plantamour recounted to us the anomalies of temperature observed at Geneva during the month of December, 1868. The mean was 7°.14, (45° F.;) being 6°.14 (43° F.) higher than for the previous forty-three years. During that period there had been but two months of March and a single November in which the temperature was higher. So high a temperature had not been experienced for any month of February, nor *a fortiori* of January, but, again, there had been six Aprils in the same series of years which were colder. There fell in December 155 millimetres (6 inches) of water, a quantity greater than that of all the years since 1826, with the exception of 1841. According to M. Wolf, of Zurich, the quantity of water collected at several stations of East Switzerland, especially at those of considerable elevation, from the middle of September to the end of October, 1867, exceeded a metre, and cases occurred in which the quantity of water falling in the course of

twenty-four hours amounted to 30 and 40 centimetres, (12 and 16 inches.) The inundations occasioned by falls of water so exceptional cannot be attributed solely to the removal of the forests from the mountains, however unfavorable such clearings may be. Lastly, mention was made of the shower of mud observed at Naples by Professor Claparede. The clouds, on that day, had a peculiar aspect and seemed to be formed of dust; muddy spots were left on the windows by the drops of rain. General Dufour had witnessed at Corfu showers of mud which the inhabitants attributed to the wind of Africa.

§ 3.—Mathematics and Physics.

Pure mathematics has been the subject of but a single memoir, which was read to us by Professor De La Harpe. It is the first part of a treatise on the formation of powers, in which the author demonstrates that the higher powers are formed by differences. He gives the formulas designed for the calculation of high powers and designates them by the general name of *formula of the monome.* This memoir was accompanied by models intended to facilitate the understanding of the demonstrations.

The geodesic labors undertaken by Swiss savants have been continued during the year 1868. Professor Plantamour has communicated to us the result of the Swiss levelings, which embrace the whole of the western part from Geneva to Basle. MM. Plantamour and Hirsch have been engaged in determining for the different stations the numbers as referred to the stone of Niton, which serves as the point of departure, while the primitive data simply give the difference of level between two consecutive stations. The number of points for which the amounts have been thus established is 626. To that end, it was necessary to make a compensation for the errors in the system composed of a series of polygons, each of which ought to be exactly closed. One of the causes of error in a leveling of precision, the influence of which is very considerable in a country so broken as ours, is the variableness in the absolute length of the sights, according to atmospheric circumstances, the temperature, hygrometric state; and, from direct and numerous comparisons, this variation may amount to a ten-thousandth of their length, more or less.

M. Plantamour gave an account of observations which he had made during a sojourn of nearly two months at Weissenstein with a view of determining the astronomical co-ordinates of that station. He also read a memoir on the latitude of the Righi Culm from observations made at that locality in 1867. The latitude was determined as well by the circum-meridian zenithal distances of stars as by observations of their passage in the prime vertical. The number obtained is sensibly greater than that indicated in the triangulation of Switzerland, which had been deduced from the latitude of Berne by the calculation of triangles. The difference is easily explained by the attraction of the neighboring chain of the Alps situated to the south of the Righi.

The effects of lightning on trees have been studied by Professor Colladon in the case of sixteen poplars, three oaks, a fir tree, and a vine. The poplars which were struck were seamed with furrows, greatly shattered, and stripped of bark and liber in the two lower thirds of the tree, the upper third being most frequently exempt from injury, probably in consequence of the greater conductibility of that portion of the branches and foliage. The poplar of Italy especially attracts lightning, for M. Colladon has seen it struck in preference to neighboring oaks and elms, though the latter were taller than the poplars. The effects of lightning on oaks are very different from those just described: the upper parts

are always killed, and one or two furrows may be traced descending from the summit to the soil. To the right and left of the furrow are seen two strips of alburnum deprived of bark, the width of which increases as they approach the ground. The effects of the lightning which fell, on the 17th of July, on a fir tree in the city of Nyon were very remarkable. The stroke was preceded by the appearance of a luminous ball which moved along the surface of the ground at three or four yards from the tree, an electric phenomenon often described by physicists and in particular by Arago. The fir was about 16.50 metres (54 feet) in height. In its upper part the leaves were scorched to the half of their length. The trunk showed no injury in its upper half, but below there were several very deep fissures and ten or twelve brownish and circular spots from 3 to 5 centimetres (1 to 2 inches) broad, where the bark had been removed. The vine struck, in July, 1868, presented a regular circle of 14 to 15 metres, (45 to 50 feet,) comprising about three hundred and fifty stems, on which nearly all the leaves were mottled with reddish and olive-colored spots. The intensity of this coloration increased on approaching the center. The props were neither burned nor broken. Dr. Müller, who examined the branches and leaves of the vine-stocks reached by the lightning, found that there was no modification of the cellules in the interior, and that the effect had taken place on the nitrogenized matter, and especially on the cambium.

The memoir of M. Colladon was accompanied with designs, samples, and strips of the bark, which greatly contributed to the understanding of the effects of lightning on the trees. Professor De La Rive cited some observations in confirmation of those of M. Colladon. He thinks that the spots observed are analogous to those of every electric discharge, and which are also circular. Their appearance would seem referable to the presence on the trunk of some foreign substance.

Professor De La Rive communicated to us the result of the observations of M. Wild on the absorbent power of light by atmospheric air, and gave us the analysis of the most recent investigations of M. Becquerel and M. Tyndall on the physical and chemical phenomena of light. He called our attention to the observations which have been made at the observatory of Greenwich on the agreement of magnetic and galvanomètric curves. These curves are nearly identical, the only difference being the following: A point of a curve of the galvanometer always precedes the corresponding point of the curve of the magnetometer.

M. Ed. Sarasin communicated the result of his researches on the phosphorescence of rarefied gases after the passage of the electric spark, and particularly on the part borne by oxygen in these phenomena, (*Archives*, March, 1869.)

Professor Marignac detailed his experiments on the heat of the volatilization of ammoniacal salts. He has arrived, by prolonged and minute researches, at the conclusion that it is exceedingly probable that the salts of ammonium are, in great part, decomposed into their elements when volatilized, (*Archives*, November, 1868.)

Professor Wartmann, besides several reports on the memoirs published by other savants, gave an account of two luminous phenomena which he had had an opportunity of observing: First, a magnificent solar spectrum on the surface of the lake, seen on the road from Hermance, a phenomenon which could only be explained by a refraction followed by a reflection of the solar rays by the waves; secondly, a luminous vertical column after the setting of the sun. This meteor, of which he published a notice in 1846, is susceptible of explanation by vertical prisms of ice held in suspension in the atmosphere.

M. Soret communicated the results of recent observations on solar radiation, the intensity of which at Geneva during several days of March was very considerable and exceeded that which he had observed in summer at an altitude of 3,000 metres, (10,000 feet.) The same member presented a memoir on the polarization of the blue light from water, which has, under this condition, an almost complete analogy with the light from the sky, (*Archives*, May, 1869.)

§ 4.—Chemistry.

M. Antoine Morin stated to us the result of his experiments on the alloys of gold, silver, and copper, a subject which intimately concerns our manufactures of jewelry and horology. The most usual alloys are not only compounds but a true chemical combination, notwithstanding the difference of density of the gold and copper. There needs but simple fusion and remelting three or four times to obtain an alloy so homogeneous that the law allows only a deduction of $\frac{3}{1000}$ for those of gold and copper and of $\frac{5}{1000}$ for those of silver and copper. For this there is required a special force, which is chemical affinity, the influence of which is demonstrated by a change in the molecular state of the metals alloyed. In calculating the specific weight of alloys, we find a number greater by an eighth or a ninth than the real density of alloys of gold, and by a sixth or a seventh than the alloys of gold and native silver of Colombia. The difference is insignificant for alloys of silver and copper, but the homogeneity of the ingots is obtained with more difficulty. The augmentation of volume of the metals which enter into the alloys of gold with silver and copper is not the only indication of a chemical combination. The proportions which have been adopted in practice for jewelry of 18 and 14 carats are closely approximate to the atomic numbers which would form combinations of a definite proportion. The hypothesis that there is chemical union, and not simple mixture, seems to be confirmed by the analysis of natural alloys. In most of these the metals are found in quantities corresponding to the exact numbers of equivalents.

M. Morin has also been engaged in verifying the cause of the *rochage* which forms an accident in founding, and which consists in a rupture of the solidified crust of the metal accompanied by a jet of that which is in fusion. He thinks that the *rochage* is a phenomenon of a chemical nature, as the metal ejected has not the same composition as the rest of the ingot.

§ 5.—Geology and Paleontology.

Professor De La Rive communicated to us a letter of Professor Agassiz on the existence of ancient glaciers of considerable height and extent in the greater part of North America, particularly in the region of the prairies.

Professor Favre described the great moraines which the ancient glacier of the Rhine has deposited even in Würtemberg. He gave an account, based on the researches of two geologists of Lyons, (MM. Falsan and Chartre,) of the erratic blocks deposited by the glacier of the Rhone between Geneva and Lyons, of the geological constitution of Mount Cervin, as studied in two successive ascents by M. Giordano, of the discoveries of M. Chartre relative to the question of prehistoric man, &c. He exhibited to us a small erratic block of red porphyry, found in the environs of St. Julien, and, on several occasions, occupied our attention with the remarkable repository of smoky rock-crystals, found at the

glacier of Tiefen, near Gallenstock, in the canton of Uri. A fine group of these crystals has been given by Madame Revilliod De La Rive to our new library and will form one of the ornaments of the Revilliod hall.

M. Ernest Favre read a memoir on the fossil mollusks of the environs of Lemberg, in Gallicia. The fossils described were furnished by two principal repositories: Nagorzany and Lemberg. At the latter, the formation is constituted by a very fine and compact calcareous marl, forming a bank which exceeds 145 metres, (476 feet.) The rock of Nagorzany is a yellow, hard sandstone, in thick banks, alternating with strata of soft limestone. M. Favre has recognized in his fauna one hundred and seventy well-distinguished species of mollusks. The cephalopods abound at Nagorzany. They comprise eighteen species, of which the most characteristic is the *Belemnitella mucronata*. Here also the gasteropods are numerous and varied, amounting to one-half of the fauna. At Lemberg they are represented by only twenty-six small and scanty species. Of the acephala, forty-six species are found at Lemberg and thirty-two at Nagorzany. The brachiopods number eleven species, four of which are common to both localities. The fossil mollusks found in Gallicia characterize the lower part of the chalk *à Belemnitella mucronata*, and, consequently, the senonian formation, presenting the greatest analogy with the chalks of Westphalia, Luneburg, and the Isle of Rugen, as well as with the senonian formations of Limburg, Hainault, and the basin of Paris, which all number species common with those of Lemberg.

M. De Loriol presented a memoir which he has recently published in conjunction with M. Gillieron on the urgonian stratum of Landeron. The fauna of this stratum forms a transition between that of the neocomian and that which characterizes the lower urgonian stratum. This fauna comprises a great number of *Spongitaria* as well as numerous individuals of a *Comatula* with single arms, pertaining to the new genus *Ophiocrina*.

§ 6.—BOTANY.

The most prominent fact which has distinguished our sessions, so far as botany is concerned, has undoubtedly been the liberal donation which Madame Delessert and her two daughters have made to the city of Geneva of the rich and celebrated herbarium of the Baron François Delessert.

This collection forms one of the twenty or twenty-one largest herbariums in existence, and it is especially remarkable on account of the great number of specimens described and mentioned by ancient or modern authors. Independently of the types described by Lamarck, Labillardière, Richard, Palisot, De Beauvais, and others, which are in the general herbarium, it comprises moreover that of the Burmans, which includes the types of the older botanists, especially those of Thunberg and of the Burmans themselves, besides a herbal of Lapland, collected and named by Linnæus. The plants of India, arranged by Wallich, form one of the most extensive collections which exist on the continent. This Delessert herbarium will be found in future in convenient proximity with the rich collections of MM. De Candolle and Boissier, which were already of easy access to botanists, so that the one will be completed by the others, thus affording facilities for the most thorough study.

It is to M. Alphonse de Candolle, than whom no one can better appreciate the importance of this gift to our city, that I am indebted for the above particulars. It was from him also that the society received, on the authority of a letter from M. De Gelaznow, director of the Agricul-

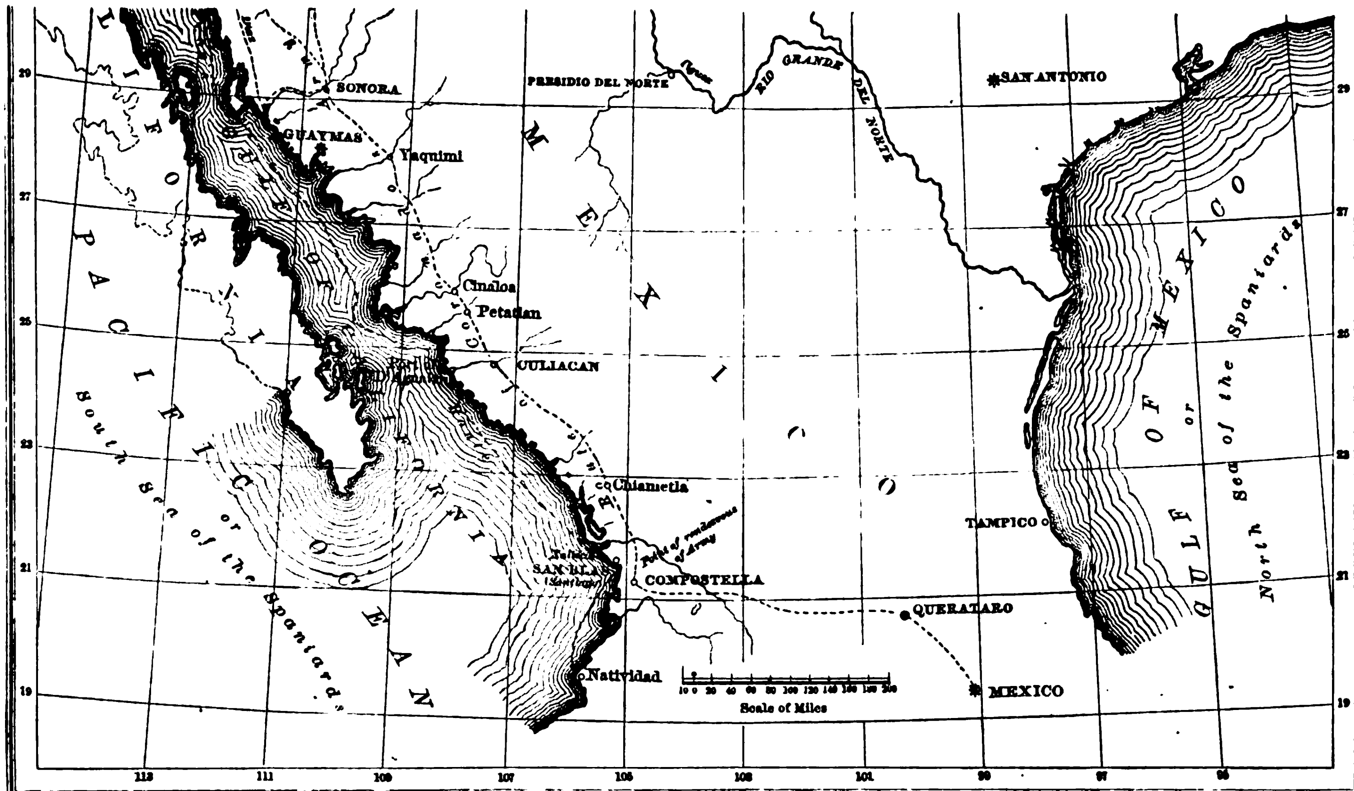
Dr. Prevost communicated to us his researches in experimental physiology relative to the seat of the sense of smell. This memoir has been published in the March number (1869) of the *Archives des sciences physiques et naturelles.* He also made us acquainted with the experiments which he had performed at Paris and Berlin in the extirpation of the spheno-palatine ganglion, an operation which, in the opinion of Dr. Schiff, must suppress the sense of taste in the anterior part of the tongue. The experiments in question gave, however, a negative result. M. Prevost also recalled the experiments of Dr. Waller on the atrophy of the peripheral nerves when separated from the central trunk. According to this learned physiologist, if the vidian branch of the lingual nerve received gustatory nervous fibers, this branch would be atrophied after the section of the spheno-palatine ganglion; this, however, has not been found to be the case by M. Prevost, who has always found it unimpaired after the operation.

Dr. Dor gave an account of new experiments made with a view to determine the velocity of the transmission of sensations.

Dr. Gosse presented skulls found by Dr. Forel de Morges in an ancient cemetery near Saint-Prex. These skulls are artificially deformed for the purpose of producing a frontal depression. Similar cases had been previously observed by M. Troyon near Lausanne, and by M. Gosse near Regny. This flattening of the front by means of a board was a national custom among certain tribes, and especially among the Avari. Depressed skulls have been found at Vienna, in the Crimea, and at Vancouver's Island. A traveler in China relates that they occur also in Mongolia, in very ancient skulls. A memoir published at St. Petersburg designates them by the name of *macrocephalic*, but this term might create some confusion with the Macrocephali of Hippocrates and Strabo, among whom the object was rather to produce protrusion of the frontal bone. This frontal depression causes ordinarily a certain degree of prognathism; it does not impair the functions of mobility, but simply lowers the grade of intelligence.

Such is a summary review of the facts which have occupied our sessions. It will be seen that they are alike numerous and varied, and furnish renewed testimony of the scientific zeal which still subsists among us. May our unpretending labors have the effect of enlarging the field of human knowledge, and consequently of promoting the diffusion of light in our country. We shall thus have accomplished, as far as depends on us, the purpose which presided at the foundation of our society; a society which already counts nearly eighty years of existence.

NEBRASKA
KANSAS
TEXAS
MISSOURI RIVER
OMAHA
PLATTE RIVER
PROVINCE OF QUIVIRA
Leavenworth
Coronado attained 40° of North Latitude
KANSAS R.
ARKANSAS RIVER
Point of separation
Salt Plains
CANADIAN RIVER
Antelope Hills
MAIN RED RIVER
RIO PECOS
El Paso
San Elezario
TAOS
SANTA FE
Las Vegas
Pecos
MOQUIS
(Tusayan)
Gran Chaco
San Francisco Mt.
COLORADO
VIRGEN
RIO GILA
Ft. YUMA
TUCSON
Chichiltieale
Point reached by Alarcon in boats
Alarcon's Cross and Letters found by Diaz
Lowest point reached by the officers of Coronado.
Route of Coronado's Army
Coronado's Route
Cardenas' return Route


MEXICO
GULF OF MEXICO
or
North Sea of the Spaniards
PACIFIC OCEAN
or
South Sea of the Spaniards
SAN ANTONIO
PRESIDIO DEL NORTE
RIO GRANDE DEL NORTE
SONORA
GUAYMAS
Yaquimi
Cinaloa
Petatlan
CULIACAN
Chiametla
Point of rendezvous of Army
COMPOSTELLA
SAN BLAS
Natividad
TAMPICO
QUERATARO
MEXICO
Scale of Miles
10 0 20 40 60 80 100 120 140 160 180 200
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19
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CORONADO'S MARCH IN SEARCH OF THE "SEVEN CITIES OF CIBOLA" AND DISCUSSION OF THEIR PROBABLE LOCATION.

By Brevet Brigadier General J. H. SIMPSON, *Colonel of Engineers, U. S. A.*

The early Spanish explorations in Mexico in search of the "seven cities of Cibola" have always been of great interest to students of American history. Recent publications have drawn my attention anew to the vast geographical field embraced in the toilsome march of Vasquez de Coronado and his adventurous followers, and, having in years past been engaged officially in the United States service in exploring that remote region, I have been tempted to reinvestigate the grand enterprise of the Mexican government in 1540, and venture to offer the following essay as an expression of my well-considered views, derived, in early life, from observation of the field itself, and confirmed by careful study of all the authorities within my reach. Besides this, friends, in whose opinion I trust, believe that my reconnoissances of a large part of the country traversed by Coronado and his followers give me some advantages in the discussion of this subject over other investigators, who have not been favored by personal inspection and scientific location of the important points embraced in the adventurers' march, so that I now submit my conclusions with less diffidence than I should have done had I not received in advance their cordial encouragement.

I must acknowledge my indebtedness to the library of the Peabody Institute of this city, to the library of the Historical Society of Maryland, and to the private library of the president of this last-mentioned society, Colonel Brantz Mayer, all of which have been thrown open to me in my researches. I must also express my particular obligations to Colonel Mayer for the very valuable aid he has afforded me in the preparation of this article, by the use of his excellent translation (yet in manuscript) of Ternaux Compans' version of the "Relation du Voyage de Cibola," entrepris en 1540, par Pédro de Castañeda de Nagera," published in Paris in 1838.

The arrangement of the following essay is, first, a brief narrative of the march of Coronado from the city of Mexico to the "seven cities of Cibola" and the province of Quivira, together with an account of the expeditions of his subordinate officers, naval and military; and second, the discussion of the subject of the location of the important places visited in the several expeditions; and, in order to a clear understanding of the text, I accompany it with a map, for which, under my direction as to details of route, I am indebted to Mr. N. H. Hutton, civil engineer, whose knowledge of New Mexico and Arizona, derived from his association with Generals Whipple and Parke, as assistant engineer, in their explorations in New Mexico and Arizona in 1853–'56, has been of material service to me.

In the year 1530, Nuño de Guzman, president of New Spain, was informed by his slave, an Indian, from the province of Tejos, situated somewhere north from Mexico, that in his travels he had seen cities so large that they might compare with the city of Mexico; that these

cities were seven in number, and had streets which were exclusively occupied by workers in gold and silver; that to reach them a journey of forty days through a desert was required; and that travelers penetrated the interior of that region by directing their steps northwardly between the two seas.

Nuño de Guzman, confidently relying on this information, organized an army of four hundred Spaniards and twenty thousand Indian allies of New Spain,* and set out in search of these seven wonderful cities; but, after reaching the province of Culiacan, he encountered such great difficulties on account of the mountains he had to cross that he abandoned the enterprise, and contented himself with colonizing the province of Culiacan.

In the mean time, the Tejos Indian who had been his guide dying, the seven cities remained only known by name, till about eight years afterward, when there arrived in Mexico three Spaniards named Alvar Nuñez Cabeça de Vaca, Andrès Dorantes, and Alonso del Castillo Maldonado, accompanied by an Arabian negro named Estevanico, (Stephen.)† These persons had been wrecked with the fleet which Pam-

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* Castañeda's Relations, Ternaux Compans' Collections, Paris, 1838, p. 2. Hakluyt, quoting from a letter written by the Viceroy Antonio de Mendoça to the Emperor Charles V, says: "Nuño de Guzman departed out of the city of Mexico, with 400 horsemen and 14,000 Indians." (Hakluyt's Voyages, vol. iii, p. 436, new ed. London, 1810.)

† This is according to Castañeda's account; but according to that of Cabeça de Vaca, Ternaux Compans' Collections, these persons arrived in New Spain in 1536, or six instead of eight years after Nuño de Guzman's expedition. Their adventures were so remarkable I cannot refrain from saying something about them:

Pamphilo de Narvaez sailed from the West Indies early in 1528, with four hundred men, eighty horses, and four ships, for the purpose of exploring the country of Florida, of which he had been made governor. He seems to have reached the harbor of Santa Cruz (supposed to be Tampa Bay) in April of that year, and on the 1st May debarked with three hundred men, forty of whom were mounted, for the purpose of exploring the interior of the country. His course was northwardly, and generally parallel to the coast. On the 26th June he reached an Indian town called *Apalache*, where he tarried twenty-five days. He then journeyed in nine days to a place called Aute. Continuing his course thence westwardly for several days, his men became so dispirited from finding no gold, and on account of the rough treatment of the natives, that they returned to Aute, where, hearing nothing of their ships, which had been ordered to coast along with them and await their arrival at some good harbor, they constructed five small boats, in which two hundred and fifty of the party (all who had not died or been killed by the natives) embarked, steering along the coast westwardly for Panuco, on the coast of Mexico. At length they reached the mouth of a river, the current of which was so strong as to prevent their making headway against it, and whose fresh water was carried out some distance into the gulf. About seven days after, while making their way with great difficulty westwardly, the boat commanded by Cabeça de Vaca was cast on an island, called by them Malhado, (Misfortune.) A day or two after this Cabeça de Vaca's boat and all the others were capsized in a storm off the island of Malhado, except that of the governor of Narvaez, which seems to have drifted out to sea, and, with its crew, was never afterward heard of. Those of the party that were not drowned remained on the island of Malhado and main land adjacent for six years, and endured from the Indians, who had enslaved them, the greatest indignities. From this cause, and from starvation and cold, the greater portion of them died. At length four of them, (those mentioned in the text above,) all that probably survived, escaped from their bondage, taking in their flight a northern course, toward the mountains, probably, of Northern Alabama. Thence their course was westwardly across the Mississippi (which was doubtless "the great river coming from the North," spoken of by Cabeça) and Arkansas rivers, to the headwaters of the Canadian, which they seem to have crossed just above the great cañon of that river, (where Coronado crossed it in his outward route to Quivira, of which more in the sequel;) thence southwestwardly through what is now New Mexico and Arizona to Culiacan, in Old Mexico, near the Pacific Coast, which they reached in the spring of 1536. (See narrative of Alvar Nuñez Cabeça de Vaca, translated by Buckingham Smith, Washington, 1851; and, in confirmation of the above specified crossing of the Canadian River, "The Relations of Castañeda, by Ternaux Compans," p. 120.)

Mr. Albert Gallatin, in his essay, vol. 2, pp. 56, 57, Transactions of American Ethno-

philo de Narvaez had conducted to Florida, and after crossing the country from one sea to the other had reached Mexico.

The tales they told were quite marvelous. They stated to the then viceroy, Don Antonio de Mendoça, that they had carefully observed the country through which they had passed, and had been told of great and powerful cities, containing houses of four or five stories, &c. The viceroy communicating these declarations to the new governor, Francisco Vasquez de Coronado, the latter set out with haste to the province of Culiacan, taking with him three Franciscan friars, one of whom, by name Marcos de Niça, in the language of the chronicler Castañeda, was theologian and priest. As soon as he reached Culiacan he dispatched the three Franciscans, with the negro Stephen before mentioned, on a journey of discovery, with orders to return and report to him all they could ascertain by personal observation of the seven celebrated cities. The monks, not being well pleased with the negro on account of his excessive avarice, sent him in advance to pacify the Indians through whose country he had previously passed, and to prepare the way for the successful prosecution of their journey. Stephen, as soon as he reached the country of the "seven cities of Cibola," demanded, as Castañeda says, not only their wealth but their women.

The inhabitants not relishing this killed him and sent back all the others that had accompanied him, except the youths, whom they retained. The former, flying to their homes, encountered the monks before mentioned, in the desert sixty leagues from Cibola.* When the holy fathers heard the sorrowful intelligence of the death of Stephen, they became so greatly alarmed that, no longer trusting even the Indians who had accompanied the negro, they gave them all they possessed except the ornaments used in the celebration of the mass, and forthwith returned, by double-days' journey, without knowing more of the country than the Indians had told them. The monks returning to Culiacan, reported the results of their attempted journey to Coronado, and gave him such a glowing description of all the negro had discovered and of what the Indians had told them, "as well as of the islands filled with treasure, which they were assured existed in the Southern sea,"† that he decided to depart immediately for Mexico, taking with him Friar Marcos de Niça, in order that he might narrate all he had seen to the viceroy. He also magnified the importance of the discovery by disclosing it only to his nearest friends, and by pledging them to secrecy.

Arrived at Mexico, he had an interview with the viceroy, and proclaimed everywhere that he had found "the seven cities" searched for by Nuño de Guzman, and busied himself with preparing an expedition for their conquest. Friar Marcos having been made, through the influence of the monks, the provincial of the Franciscans, their pulpits re-

logical Society, states that the river referred to above, whose current was so strong and which Narvaez's party could not stem, was the Mississippi; but this is not the view of Mr. Smith, who has laid down the routes of Narvaez and party as extending no further west than *Leaf River*, which lies to the eastward of the Mississippi River. His idea, however, that the island of Santa Rosa, at the mouth of Pensacola Bay, was Malhado, I think erroneous, for the reason that Cabeça de Vaca expressly says this island was "half a league broad and five leagues (or seventeen miles) long," whereas Santa Rosa Island, according to the maps, is as much as forty-seven miles long. It is possible, however, that by accretions the island may have attained this length since Cabeça de Vaca was wrecked upon it.

* So says Castañeda; but Marcos de Niça, in his account of his journey, distinctly states that he approached so near the city of Cibola that from a high elevation he could see the houses, and gives quite a particular description of them. (Relation of Friar Marcos de Niça, Ternaux Compans' Collections, p. 279.)

† Castañeda's Relations, Ternaux Compans, p. 16.

sounded with the marvels of discoveries to such an extent that in a few days three hundred Spaniards and eight hundred Indians were assembled for the enterprise. Among the former were a great many gentlemen of good family, and probably there never had been an expedition in which there was such a large proportion of persons of noble birth. Francisco Vasquez de Coronado, the governor of New Galicia, was proclaimed captain general, because he was the author of the discovery, and the Viceroy Mendoça did all he could to foster the enterprise.

Believing that if the army marched from the city of Mexico in a body the Indian allies would probably suffer, the viceroy appointed the town of Compostella, capital of New Galicia, one hundred and ten leagues from Mexico, as the place, and Shrove Tuesday, 1540,* the time of rendezvous. The troops having left Mexico, he ordered Don Pedro d'Alarcon to depart for La Nativitad, on the coast of the "Southern Sea," and with two vessels to go to Jalisco to take the supplies which the soldiers could not transport. After performing that duty he was to follow the march of the army along the coast, for it was believed, according to the then received accounts, that the army would never be distant from the vessels, and would always be in easy communication with them by means of the rivers.†

All these dispositions having been made, the viceroy departed for Compostella with a large body of gentlefolks. Everywhere he was received with great *éclat*, and when he reached Compostella he found the army well lodged and entertained by Christoval d'Onate, captain general of that country.

He reviewed the troops, by whom he was received with great rejoicing, and the next day after mass harangued them. He told them of their duties and of the advantageous result that this conquest would produce, not only on their fortunes, but by the conversion of the nations they would conquer, as well as for the service of his Majesty, who on his side promised them his bounty and additional favors. Finally he caused every one to be sworn on a missal containing the Holy Evangels not to abandon their general and to obey all his commands.

The next day the army with banners flying took up the line of march. For two days the viceroy accompanied it, and then returned to Mexico. No sooner, however, had the viceroy left the army than it began to experience all the hardships incident to a wild, mountainous country. The baggage had to be transported on horses, and, as many soldiers had never been accustomed to load them, they made sorry work of it. The consequence was that a great deal of their baggage was abandoned, and in order to get along at all many a gentleman had to become a muleteer, and they who shirked from this necessary labor were regarded by their companions as lacking spirit.

Coronado arriving at Chiametta with his army, met at that point Captains Melchior Diaz and Juan de Saldibar, who with a dozen resolute men, by Coronado's orders, had explored the country as far as Chichilticale, which is on the border of the desert and two hundred leagues from Culiacan.‡ These officers gave in secret to the general such a dole-

* Castañeda's Relations, Ternaux Compans, p. 24. Castañeda says 1541, but, as Ternaux Compans has remarked in a note, he evidently must have made a mistake, for the letter of the viceroy to the Emperor Charles V, reporting the organization and progress of the expedition, bears date April 17, 1540.

† According to "Los Tres Siglos de Mexico, tom. I, Mexico, 1836," p. 129, "Mendoça dispatched Alarcon, with two ships, to observe the coast as far as the 36th degree of latitude, with instructions to make frequent embarkations and to join the army at that height."

‡ Castañeda gives in one place two hundred leagues as the distance; and in another, two hundred and twenty leagues. See his Rel. Ternaux Compans' Col., pp. 12, 29.

ful account of the country they had passed through, that, it leaking out, many in the army began to lose heart; and it was only by Friar Marcos de Niça insisting upon it, that the country was a good one, and that they should not leave it with empty hands, that they were persuaded to continue the march.

The day after Easter, the army took up its march for Culiacan, at which place they were well received by the citizens and furnished with all necessary supplies. This was the last town inhabited by Spaniards, and, therefore, the last from which they could gather provisions, except from the Indians with whom they might meet in their further march. It is represented by Castañeda, as being two hundred and ten leagues from the city of Mexico.*

After resting a couple of weeks at Culiacan, Coronado led the advance of his army, consisting of fifty cavaliers, a few infantry, his particular friends, and the monks, leaving the rest of the army with orders to march a fortnight after, and to follow his path. As Castañeda, describing his progress, expresses it, "when the general had passed through all the inhabited region to Chichilticale, where the desert begins, and saw that there was nothing good, he could not repress his sadness, notwithstanding the marvels which were promised further on. No one save the Indians who accompanied the negro had seen them, and already on many occasions they had been caught in lies. He was especially afflicted to find this Chichilticale, of which so much had been boasted, to be a single, ruined, and roofless house, which at one time seemed to have been fortified. It was easy to see that this house, which was built of red earth, was the work of civilized people who had come from afar.

"On quitting this place they entered the desert. At the end of fifteen days they came within eight leagues of Cibola, on the banks of a river which they named *Vermejo*, in consequence of its red and troubled water. Mullets resembling those of Spain were found in it. It was there that the first Indians of the country were discovered; but when these saw the Spaniards they fled and gave the alarm. During the night of the succeeding day, when not more than two leagues from the village, some Indians who were concealed suddenly uttered such piercing cries that our soldiers became alarmed, notwithstanding they pretended not to regard it as a surprise; and there were even some who saddled their horses the wrong way, but these were men who belonged to the new levies. The best warriors mounted their horses and scoured the country. The Indians, who knew the land, escaped easily, and not one of them was taken. On the following day, in good order, we entered the inhabited country. Cibola was the first village we discovered; on beholding it the army broke forth with maledictions on Friar Marcos de Niça. God grant that he may feel none of them!

"Cibola is built on a rock; this village is so small that, in truth, there are many farms in New Spain that make a better appearance. It may contain two hundred warriors. The houses are built in three or four stories; they are small, not spacious, and have no courts, as a single court serves for a whole quarter. The inhabitants of the province were united there. It is composed of seven towns, some of which are larger and better fortified than Cibola. These Indians, ranged in good order, awaited us at some distance from the village. They were very loth to accept peace; when they were required to do so by our interpreters, they menaced us by their gestures. Shouting our war-cry of Sant Iago, we charged upon and quickly caused them to fly.

* Castañeda's Rel., Ternaux Compans' Col., p. 149.

"Nevertheless, it was necessary to get possession of Cibola, which was no easy achievement, for the road leading to it was both narrow and winding. The general was knocked down by the blow of a stone as he mounted in the assault, and he would have been slain had it not been for Garci Lopez de Cardenas and Hernando d'Alvarado, who threw themselves before him and received the blows of the stones which were designed for him and fell in large numbers; nevertheless, as it is impossible to resist the first impetuous charge of Spaniards, the village was gained in less than an hour. It was found filled with provisions which were much needed, and, in a short time the whole province was forced to accept peace."*

The main army, which had been left at Culiacan under the command of Don Tristan d'Arellano, followed Coronado as directed by him, every one marching on foot, with lance in hand and carrying supplies. All the horses were laden. Slowly and with much fatigue, after establishing and colonizing Sonora, and endeavoring to find the vessels under Alarcon already referred to, by descending the river, in which they failed, the army reached Cibola. Here they found quarters prepared for them and rejoiced in the reunion of the troops, with the exception of certain captains and soldiers who had been detached on explorations.

Meantime, Captain Melchior Diaz, who had been left at Sonora, placed himself at the head of twenty-five choice men, and under the lead of guides directed his steps towards the southwest in hopes of discovering the coasts. His course was probably down the Rio Sonora, and not finding the vessels there he doubtless marched northward, keeping as close to the coast as the rivers would permit him. After traveling about one hundred and fifty leagues† it appears he arrived in a country in which there was a large river, called Rio del Tizon, whose mouth was two leagues wide. Here the captain learned that the vessels under Alarcon had been on the sea-coast, at a distance of three days' journey from that place. In the language of Castañeda, "When he reached the spot that was indicated, and which was on the bank of the river more than fifteen leagues from its mouth, he found a tree on which was written 'Alarcon has come thus far; there are letters at the foot of this tree.' They dug and found the letters, which apprised them that Alarcon, after having waited a certain length of time at that spot, had returned to New Spain, and could not advance further because that sea was a gulf; that it turned around the Isle of the Marquis, which had been called the Isle of California, and that California was not an island, but a part of land forming the gulf."‡

It appears that after a good deal of difficulty and a threatened attack from the natives, the party crossed the Rio del Tizon, on rafts, some five or six days' travel higher up, and continued its journey along the coast. Quoting from Castañeda, "When the explorers had crossed the Rio del Tizon, they continued following the coast, which at that place turns toward the southeast, for this gulf penetrates the land directly toward the north, and the stream flows exactly toward the mouth from north to south."§ No better description could be given of the relative position of the Gulf of California, with respect to the Rio Colorado flowing into it from the north, than the foregoing.

This expedition was terminated by the death of Melchior Diaz, which occurred in a very singular manner, as follows: "One day a greyhound belonging to a soldier attacked some sheep which the Spaniards were

* Castañeda's Relations, Ternaux Compans, pp. 40, 41, 42, 43.
† Castañeda's Relations, Ternaux Compans, p. 49.
‡ Castañeda's Relations, Ternaux Compans, pp. 50, 51. § Ibid, p. 104.

driving with them to serve as food in case of need, when Captain Melchior Diaz threw his lance at the beast, in order to drive him off. Unfortunately the weapon stuck in the ground with the point uppermost, and as Diaz could not rein in his horse, who was at a gallop, quickly enough, it pierced his thigh through and through, and severed his bladder. The soldiers at once decided to retrace their steps, taking their wounded chief with them. The Indians, who were always in rebellion, did not cease attacking them. The captain lived about twenty days, during which he was borne along with the utmost difficulty. When, at length, he died, all his troops returned in good array, (to Sonora,) without the loss of a single man, and after traversing the most dangerous places."*

In this connection it may be interesting to give some account of Alarcon's discovery of the Rio Colorado. It will be recollected that he was ordered by the Viceroy Mendoça to follow the march of the army with his vessels along the coast of the Southern Sea, as the Pacific Ocean was then called. From his relation to the viceroy † I gather the following:

On the 9th of May, 1540, Fernando Alarcon put to sea from La Natividad, in command of two ships, the Saint Peter and the Saint Catherine. He put into the ports of Xalisco and Agnaival, (respectively the ports of Compostella and Culiacan,) and finding Coronado and his army gone from this last-mentioned place, he continued his course northwardly along the coast, taking with him the ship St. Gabriel, which he found there laden with supplies for the army. At length arriving towards the upper end of what was till then believed to be a strait separating an island from the main land, but which he discovered to be a gulf, (the Gulf of California,) he experienced great difficulty in navigating, even with his small boats; and there were some in the expedition, he remarks, who lost heart and were anxious to return, as did Captain Francisco de Ullva, with his vessels, in a former voyage of discovery. Alarcon, it seems, however, had the necessary pluck, and, agreeably to the orders of the Viceroy Mendoça, he was determined to make his explorations as thorough as possible. After incredible hardships he managed to get his vessels to the bottom of the gulf, ("*au fond du gulfe.*") Here he found a very great river, the current of which was so rapid, that they could scarcely stem it. Taking two shallops and leaving the others with the ships, and providing himself with some guns of small caliber, on the 26th of August, 1540, he commenced the ascent of the river by hauling the boats with ropes.‡ On his way he met a large number of Indians,

* Castañeda's Relations, Ternaux Compans, p. 105.

† Ternaux Compans' Coll., p. 299–348.

‡ The most reliable information in relation to the Colorado River will be found in the report of Lieutenant Ives's ascent of that stream in 1858. (Ex. Doc. No. —, 36th Congress, 1st session.) * * * * * * * *

"From his account the region at the mouth of the Colorado is a flat expanse of mud, and the channels that afford entrance from the gulf are shifting and changeable. For 30 miles above the mouth the navigation is rendered periodically dangerous by the strength and magnitude of the spring tides.

"Between the tide-water and Fort Yuma, which is 150 miles from the mouth, the principal obstructions are sand-bars, continually shifting, having in some places but two feet of water upon them. There are no rocks, but snags are numerous although not very dangerous.

"For 180 miles above Fort Yuma the navigation is similar. The river passes through several chains of hills and mountains, forming gorges or cañons, sometimes of a considerable size. In these there is generally a better channel than in the valley.

"In the next 100 miles gravelly bars are frequent, with many stretches of good river and although the bad places are worse, the channel is better than below. For the succeeding 50 miles there are many swift rapids. The river bed is of coarse gravel and sand, and there are some dangerous sunken rocks. The Black Cañon, which is 25 miles

who made signs to him to return down the river, but by good management he so appeased them that he was enabled to reach a distance above the mouth of the river, such that in two and a half days, on his return to the ships, on account of the swiftness of the current, he made the same distance he had in fifteen and a half days in ascending the river. On this expedition he learned from the Indians he met, some particulars of the death of the negro Stephen, before referred to, at Cibola, and of there being white persons like themselves at that place, who doubtless belonged to Coronado's army. Alarcon was, however, unable to communicate with the army on account of the desert intervening between them, and the great distance they were apart.

Refitting all his shallops this time for a second voyage up the river, he left its mouth on the 14th of September, but was no more successful in this than in his former expedition in communicating with Coronado. Having, therefore, reached as far up the river as he thought expedient, he planted a cross at that point, and deposited at its foot some letters, in the hope that some persons of Coronado's army, searching for news of the vessels, might find them. These letters, it has already been stated, were found by Melchior Diaz on the Rio del Tizon, called by Alarcon the "Bon Guide," after the device of his lordship Don Antonio de Mendoça, and at the present day the Rio Colorado.

At the end of Alarcon's relation to the viceroy he reports that he found the latitude, as given by the "patrons and pilots of the Marquis del Valle," wrong by two degrees; that he had gone further by four degrees than they, and that he had ascended the river a distance of eighty-five leagues.* This report of Alarcon's is very interesting from its great particularity and the many incidents it gives of the expedition; it shows also that he was fully equal to the trust committed to him, and that no explorer could have done more to carry out the orders of the Viceroy Mendoça.

We will now return to the army under Coronado, at Cibola. This general immediately set to work to explore the adjacent country. Hearing there was a province in which there were seven towns similar to those of Cibola, he dispatched hither Don Pédro de Tobar with seventeen horsemen, three or four soldiers, and Friar Juan de Padilla, a Franciscan, who had been a soldier in his youth, to explore it. "The rumor had spread among its inhabitants that Cibola was captured by a very ferocious race of people who bestrode horses that devoured men, and as they knew nothing of horses, this information filled them with the greatest astonishment."† They, however, made some show of resistance to the invaders in their approach to their towns, but the Spaniards charging upon them with vigor, many were killed, when the remainder fled to the houses and sued for peace, offering, as an inducement, presents of cotton stuff, tanned hides, flour, pine nuts, maize, native fowls, and some turquoises.

These people informing the Spaniards of a great river on which there

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long, is now reached, and in it the rapids are numerous and difficult. Calville is some six miles above the head of this cañon." (Letter of General A. A. Humphreys, Chief of Corps of Engineers United States Army, to Secretary of War, June 24, 1868, in his annual report for 1868, part 2, p. 1195.)

* Alarcon's orders from the Viceroy Mendoça, as before stated, in a note, were to explore as high as the 36th degree of latitude. According to his own account of the distance he went up the Rio del Tizon, (Colorado,) he must have explored as far as about the 34th degree, and if he went no higher up than where Melchior Diaz found the tree, at the foot of which were letters from Alarcon, showing that there was the highest point to which he had attained, the highest latitude he reached must have been only about the 33d degree.

† Castañeda's Relations, Ternaux Compans, p. 59.

were Indians living, who were very tall, a report of the same on his return to Cibola was made by Don Pedro de Tobar to Coronado, who sent out another party consisting of twelve men, under Don Garci-Lopez de Cardenas, to explore this river. It appears from Castañeda's Relations that the party passed through Tusayan again on its way to the river and obtained from its inhabitants the necessary supplies and guides.

After a journey of twenty days through a desert it seems they reached the river, whose banks were so high that, as Castañeda expresses it, "they thought themselves elevated three or four leagues in the air." For three days they marched along the banks of the river, hoping always to find a downward path to the water, which from their elevation did not seem more than a yard in width, but which according to the Indians' account was more than half a league broad. But their efforts to descend were all made in vain. Two or three days afterward, having approached a place where the descent appeared practicable, the captain, Melgosa Juan Galeras, and a soldier, who were the lightest men in the party, resolved to make the attempt. They descended until those who remained above lost sight of them. They returned in the afternoon declaring that they had encountered so many difficulties that they could not reach the bottom; for what appeared easy when beheld from aloft, was by means so when approached. They added that they compassed about one-third of the descent, and that from thence the river already seemed very wide, which confirmed what the Indians stated. They assured them that some rocks which were seen from on high, and did not appear to be scarcely as tall as a man, were in truth loftier than the tower of the cathedral of Seville.*

Castañeda, after describing the further progress of the exploring party, goes on to say: "The river was the Tizon (Colorado.) A spot was reached much nearer its source than the crossing of Melchior Diaz and his people (before referred to;) and it was afterward known that the Indians which have been spoken of were the same nation that Diaz saw. The Spaniards retraced their steps (to Cibola) and this expedition had no other result."†

During the march they met with a cascade falling from a rock. The guides said that the white crystals hanging around it were formed of salt. They gathered and carried away a quantity thereof, which was distributed at Cibola.‡

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* For 300 miles the cut edges of the table land rise abruptly, often perpendicularly, from the water's edge, forming walls from 3,000 to 6,000 feet in height. This is the great cañon of the Colorado, the most magnificent gorge as well as the grandest geological section of which we have any knowledge.

Again, the cañon of the Colorado at the mouth of Grand River is but a portion of the stupendous chasm which its waters have cut in the strata of the table lands, and of which a general description has been given. At this point its walls have an altitude of over 3,000 feet above the Colorado, and the bed of the stream is about 1,200 feet above the level of the sea, or 500 feet higher than those in the Black Cañon. A few miles further east, where the surface of the table lands has an altitude of nearly 7,000 feet, the dimensions of the cañon become far more imposing, and its cliffs rise to the height of more than a mile above the river. (Report of Lieutenant Joseph C. Ives, Corps of Topographical Engineers United States Army, upon the Colorado River, 1857-'58, Senate Ex. Doc. 30th Congress, 1st session. Geology, chapter v, p. 42; Chapter vi, p. 54.)

† Castañeda's Relations, Ternaux Compans, p. 64.

‡ Lieutenant Ives speaks of having found salt on the Flax River, which Cardenas, party undoubtedly crossed or followed:

"At noon to-day we came to the object of our search—a well-beaten Indian trial' running toward the north. Camp was pitched at the place where it strikes the Flax River, and it is the intention to make the second attempt to-morrow to penetrate the unexplored region. Near by are several salt springs, and scattered over the adjacent surface are crystals of excellent salt." (Report of Lieutenant Ives, p. 117.)

I have thus briefly described the explorations which were made by Coronado and his captains, as far as Cibola, on the northern edge of the great desert northward of Chichilticale; the branch expedition of Melchior Diaz from Sonora northwestward to and around the head of the Gulf of California, after crossing the Tizon (Colorado,) in search of the vessels; the exploration of the river Tizon, by Alarcon, in boats for a distance of 85 Spanish leagues,* or about 290 miles, above its mouth; the expedition of Don Pedro de Tobar from Cibola to Tusayan, lying to the northwest of Cibola twenty-five leagues; and the exploration of Don Garci Lopez de Cardenas from Cibola through Tusayan westwardly to the deeply cañoned river Tizon. I shall now give in as few words as I can some account of Coronado's subsequent explorations to the eastward of Cibola.

While the discoveries above mentioned were being made, some Indians living seventy leagues towards the east, in a province called Cicuyé, arrived at Cibola. There was with them a Cacique, surname Bigotes (Mustaches) on account of his wearing these long appendages. They had heard of the Spaniards, and came to offer their services and their friendship. They offered gifts of tanned skins, shields, and helmets, which the general reciprocated by giving them necklaces of glass beads, and bells, which they had never before beheld. They informed him of cows, because one of these Indians had one painted on his body." Castañeda goes on to say, but "we would never have guessed it, from seeing the skins of these animals, for they are covered with a frizzled hair, which resembles wool;" † thus showing that they certainly were buffaloes.

The general ordered Captain Hernando d'Alvarado to take twenty men and to accompany these Indians, but to return in eighty days to render an account of what he might have seen. Alvarado departed with them, and "five days after they arrived at a village named Acuco, built on a rock. The inhabitants, who are able to send about two hundred warriors into the field, are the most formidable brigands in the province. This village was very strongly posted, inasmuch as it was reached by only one path, and was built upon a rock precipitous on all its other sides, and at such a height that the ball from an arquebuse could scarcely reach its summit. It was entered by a stairway cut by the hand of man, which began at the bottom of the declivitous rock and led up to the village. This stairway was of suitable width for the first two hundred steps, but after these there were a hundred more much narrower, and when the top was finally to be reached it was necessary to scramble up the three last *toises* by placing the feet in holes scraped in the rock, and as the ascender could scarcely make the point of his toe enter them he was forced to cling to the precipice with his hands. On the summit there was a great arsenal of huge stones, which the defenders, without exposing themselves, could roll down on the assailants, so that no army, no matter what its strength might be, could force this passage. There was on the top a sufficient space of ground to cultivate and store a large supply of corn, as well as cisterns to contain water and snow."‡

The Indians here, as at Tusayan, traced lines on the ground, and forbade the Spaniards to pass over them; but seeing the latter disposed

* Common Spanish league equals 3.42 American miles. (United States Ordnance Manual.)

† Castañeda's Relations, Ternaux Compans, p. 68. "Il est ici la question des bisons, que l'auteur nomme toujours *vacas*. Je me servirai dorénavant du mot de bison." (Note by Ternaux Compans.)

‡ Castañeda's Relations, Ternaux Compans, pp. 68, 69, 70.

for an attack, they quickly sued for peace, and presented to their conquerors a supply of birds' bread, tanned deer-skins, pine-nuts, seeds, flour, and corn.

Three days' journey thence Captain Alvarado and party reached a province called Tiguex, where, on account of Bigotes, whom the inhabitants knew, they were received very kindly; and the captain was so well pleased with what he saw that he sent a messenger to Coronado inviting him to winter in that country, which pleased the general greatly, as it made him believe that his affairs were growing better.

Five days' journey thence, Alvarado reached Cicuyé, a village very strongly fortified, and whose houses had four stories. He reposed here with his party some days, when he fell in with an "Indian slave who was a native of the county adjacent to Florida, the interior of which Fernando de Soto had lately explored."*

This Indian, whom they called *il Turco*, (the Turk,) on account of his resemblance to the people of that nation, spoke of certain large towns, and of large stores of gold and silver in his country,† and also of the country of the bisons, (buffaloes.) Alvarado took him as a guide to the bison country, and after he had seen a few of them he returned to Tiguex to give an account of the news to Coronado.

In the order of events, Coronado, who had remained at Cibola with the main body of the army, hearing of a province composed of eight towns, took with him thirty of the most hardy of his men and set out to visit it on his way to Tiguex. In eight or eleven days (the narrative is here obscure) he reached this province, called Tutahaco, which appears to have been situated on the Rio de Tiguex, below the city of Tiguex, for Castañeda expressly states that he afterward ascended the river and visited the whole province until he arrived at Tiguex. The eight villages composing this province were not like those of Cibola, built of stone, but of earth. He also learned of other villages still further down the river.

"On his arrival at Tiguex, Coronado found Hernando d'Alvarado with the Turk, and was not a little pleased with the news they gave him. This Indian told him that in his country there was a river two leagues wide, in which fish as large as horses were found; that there were canoes with twenty oarsmen on each side, which were also propelled by sails; that the lords of the land were seated in their sterns upon a dais, while a large golden eagle was affixed to their prows. He added that the sovereign of this region took his *siesta* beneath a huge tree, to whose branches golden bells were hung, which were rung by the agitation of the summer breeze. He declared, moreover, that the commonest vessels were of sculptured silver; that the bowls, plates, and dishes were of gold. He called gold *acochis*. He was believed because he spoke with great assurance, and because when some trinkets of copper were shown him he smelt them, and said they were not gold. He knew gold and silver very well, and made no account of the other metals. The general sent Hernando d'Alvarado to Cicuyé to reclaim the golden bracelets which the Turk pretended had been taken from him when he was made prisoner. When Alvarado arrived there the inhabitants received him kindly, as they had done before, but they pos-

* Castañeda's Relations, Ternaux Compans, p. 72. The basin of the Mississippi River and tributaries, in former days, were included in Florida by the Spaniards. (See note, p. 90.)

† The country of Quivira, which Coronada, as will be seen in the sequel, visited, and which, being adjacent to Florida, as stated above, must have been situated in the country tributary to the Missouri or Mississippi, and not near the Rio Grande, as some commentators have supposed.

itively affirmed that they had no knowledge of the bracelets, and they assured him that the Turk was a great liar, who deceived him. Alvarado, seeing there was nothing else he could do, lured the chief, Bigotes, and the Cacique under his tent, and caused them to be chained. The inhabitants reproached the captain with being a man without faith or friendship, and launched a shower of arrows on him. Alvarado conducted these prisoners to Tiguex, where the general retained them more than six months."*

This affair seems to have been the beginning of Coronado's troubles with the Indians, which were subsequently increased by his exacting a large quantity of clothing, which he divided among his soldiers.

Two weeks after Coronado left Cibola for Tiguex, agreeably to his orders, the army under the command of Don Tristan d'Arellano took up its march from that place for Tiguex. The first day they reached the handsomest, and largest village in the province, where they lodged. "There they found houses of seven stories, which were seen nowhere else. These belonged to private individuals, and served as *fortresses.* They rise so far above the others that they have the appearance of towers. There are embrasures and loop-holes from which lances may be thrown and the place defended. As all these villages have no streets, all the roofs are flat, and common for all the inhabitants; it is therefore necessary to take possession, first of all, of those large houses which serve as defenses."†

The army passed near the great rock of Acuco, already described, where they were well received by the inhabitants of the city perched on its summit.

Finally it reached Tiguex, where it was well received and lodged. The good news given by the Turk cast their past fatigues into oblivion, though the whole province was found in open revolt, and not without cause, for on the preceding day the Spaniards had burnt a village; and we have already seen that the imprisonment of Bigotes and the Turk, and the exactions of clothing by Coronada, had also very greatly exasperated them. The result of all this was that the Indians generally revolted, as they said, on account of the bad faith of the Spaniards, and the latter retaliated by burning some of their villages, killing a large number of the natives, and at last laying siege to and capturing Tiguex. This siege lasted fifty days, and was terminated at the close of 1540.‡

After the siege the general dispatched a captain to Chia, which had sent in its submission. It was a large and populous village, four leagues west of the Tiguex River. Six other Spaniards went to Quirix, a province composed of seven villages. All these villages were at length tranquilized by the assiduous efforts of the Spaniards to regain the confidence which they had justly lost by their repeated breaches of faith; but no assurances that could be given to the twelve villages in the province of Tiguex would induce *them* to return to their homes so long as the Spaniards remained in the country; and no wonder, for no more barbarous treachery was ever shown to a submissive foe than had been shown to these Tigueans by these faithless Spaniards.

So soon as the Tiguex River, (Rio Grande,) which had been frozen for four months, was sufficiently free from ice, the army took up its march on the 5th of May, 1541, to Quivira, in search of the gold and silver which

*Castañeda's Relations, Ternaux Compans, pp. 76, 77, 78.

†Castañeda's Relations, Ternaux Compans, p. 80.

‡Castañeda says 1542, evidently an error, as may be ascertained by accounting for the time consumed by the army in its march from Chiametla, which it left on the next day after Easter, 1540. (See ante, p. 12.)

the Turk had said could be found there. Its route was via Cicuyé, twenty-five leagues distant. The fourth day after leaving Cicuyé and crossing some mountains it reached a large and very deep river, which passed pretty near to Cicuyé, and was therefore called the Rio de Cicuyé. Here it was delayed four days to build a bridge. Ten days after, on their march, they discovered some tents of tanned buffalo skins, inhabited by Indians who were like Arabs, and who were called Querechaos; continuing their march in a northeastwardly direction they soon came to a village in which Cabeça de Vaca and Dorantes (mentioned in the first part of this paper) had passed through on their way from Florida to Mexico.* The army met with and killed an incredible number of buffalo,† and after reaching a point 250 leagues (850 miles) from Tiguex, the provision giving out, Coronado, with thirty horsemen and six foot-soldiers, continued his march in search of Quivira, while the rest of the army returned to Tiguex under the command of Don Tristan d'Arellano. The narrative goes on to say: "The guides conducted the general to Quivira in forty-eight days, for they had traveled too much in the direction of Florida. At Quivira they found neither gold nor silver, and learning from the Turk that he had, at the instance of the people of Cicuyé, purposely decoyed the army far into the plains to kill the horses, and thus make the men helpless and fall an easy prey to the natives, and that all he had said about the great quantity of silver and gold to be found there was false, they strangled him. The Indians of this region, so far from having large quantities of gold and silver, did not even know these metals. The Cacique wore on his breast a copper plate, of which he made a great parade, which he would not have done had he known anything about those precious metals. The army, as stated above, retreated to Tiguex before reaching Quivira. They took as guides some Teyans, through whose country they were passing, and were led back by a much more direct way than that they pursued in coming. These Teyans were a nomadic nation, and being constantly in the pursuit of game knew the country perfectly." It is narrated they guided the army thus: Every morning they watched to note where the sun rose, and directed their way by shooting an arrow in advance, and then before reaching this arrow they discharged another; in this way they marked the whole of their route to the spot where water was to be found, and where they encamped. "The army consumed only twenty-

* It will be recollected that it was on information given by these persons and two others, Maldonado and the negro Estevan, that this expedition was founded. (See ante p. 310.)

† The following minute and graphic description of the buffalo, seen by Coronado and his army, is taken from Gomara, as quoted in Hakluyt's Voyages, vol. iii. "These oxen are of the bigness and color of our bulls, but their horns are not so great. They have a great bunch upon their fore-shoulders, and more hair upon their fore part than on their hinder part; and it is like wool. They have, as it were, a horse mane upon their back bone, and much hair, and very long from the knees downward. They have great tufts of hair hanging down their foreheads, and it seemeth they have beards, because of the great store of hair hanging down at their chins and throats. The males have very long tails, and a great knob or flock at the end, so that in some respects they resemble the lion, and in some other the camel. They push with their horns, they run, they overtake and kill a horse when they are in their rage and anger. Finally, it is a fierce beast of countenance and form of body. The horses fled from them, either because of their deformed shape, or else because they had never seen them. Their masters have no other riches nor substance; of them they eat, they drink, they apparel, they shoe themselves; and of their hides they make many things, as houses, shoes, apparel, and ropes; of their bones they make bodkins; of their sinews and hair, thread; of their horns, maws and bladders, vessels; of their dung, fire; and of their calf skins, budgets, wherein they draw and keep water. To be short, they make so many things of them as they have need of, or as may suffice them in the use of this life."

five days on the journey, and even then much time was lost. The first time it had taken thirty-seven days."*

"On the road they passed a great number of salt marshes where there was a considerable quantity of salt. Pieces longer than tables and four or five inches thick were seen floating on the surface. On the plains they found an immense number of small animals resembling squirrels, and numerous holes burrowed by them in the earth."† These animals were most unquestionably the little prairie-dogs whose villages have been so naively described by Washington Irving and George Wilkins Kendall. On this march the army reached the river Cicuyé, more than thirty leagues below the place where they had before crossed it by a bridge. They then ascended the river, by following the banks, to the town of Cicuyé. The guides declared that this river, the Cicuyé, (no doubt the Pecos,) at a distance of more than twenty days' journey, threw itself into that of Tiguex, (the Rio Grande,) and that subsequently it flowed toward the east. Castañeda goes on to say: "It is believed that it (the Tiguex) joins the great river of Espiritu Sancto (Mississippi River) that the party of Hernando de Soto discovered in Florida."‡

The army under Arellano reaching Tiguex, on its return from the prairies in the month of July, 1541, this officer immediately ordered Captain Francisco de Barrio-Nuevo to ascend the Rio de Tiguex (Rio Grande) in another direction with some soldiers on an exploring expedition. They reached the provinces, one of which, comprising seven villages, was called Hemes; the other, Yuque-Yunque.

Twenty leagues (68 miles) further in ascending the river, they came to a large and powerful village named Braba, to which the Spaniards gave the new title of Valladolid. "It was built on the two banks of the river, which was crossed by bridges built with nicely-squared timber."§ The country was very high and cold. From Braba the exploring party returned to Tiguex. Another party, it seems, went down the Rio de Tiguex (Rio Grande) eighty leagues, where they discovered four large villages, and "reached a place where the river plunged beneath the ground; but inasmuch as their orders confined them to a distance of eighty leagues, they did not push on to the place where, according to the Indians' accounts, this stream escapes again from the earth with considerably augmented volume."||

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* Castañeda's Relations, pp. 133, 134.

† Castañeda's Relations, Ternaux Compans, p. 134.

‡ "VARIOUS NAMES OF THE MISSISSIPPI RIVER.—I remember to have seen in the course of my reading the following Indian, Spanish, and French names applied to the river Mississippi; and it may be well to record them in your magazine for preservation, and probably to be augmented in number by other students of American history:

"*Indian names.*—Mico—king of rivers; Mescha-Sibi-Mescha, great and Sibi River; Namosi-Sipon—Fish River; Okimo-chitto—Great Water path—a Choctá name; Misseeseepe; Meact-chassipi—old father of rivers, according to Du Pratz; Malbouchia, according to Iberville.

"*French.*—Riviere de St. Louis; Riviere de Colbert; Mississippi.

"*Spanish.*—Rio Grande; Rio Grande del Espiritu Santo; Rio de la Eulata; Rio de la Palisada; Rio de Chuchaqua.

"The VerDCi Ptolemy of 1513 lays it down, or, at least, marks a river without a name, at the site of its embouchure. Orbus Typis, 1515; Piñeda's map, 1519; other Ptolemies, 1525; Cabeça de Vaca saw it in 1528. De Soto crossed it in June, 1541, and died in Louisiana, on the west bank of the Mississippi, opposite the mouth of the Big Black River, May 21, 1542.

"BRANTZ MAYER.

"BALTIMORE, October 15, 1857."

—(See Historical Magazine, vol. 1, p. 342.)

§ Castañeda's Relations, Ternaux Compans, p. 139.

|| Castañeda's Relations, Ternaux Compans, p. 140. Mr. Albert Gallatin, commenting on this passage, says: "The assertion that the river was lost under ground was a mistake.

We shall now return to Coronado, whom we left at Quivira. It appears that, in consequence of his not arriving at Tiguex at the expected time, Don Tristan d'Arellano set out in search of him with forty horsemen. At Cicuyé the inhabitants attacked Don Tristan, by which he was delayed four days. Hearing of the approach of Coronado, he contented himself with guarding the passes in the vicinity of the village till the arrival of the general. Castañeda says that, "notwithstanding he had good guides, and was not incumbered with baggage, Coronado was forty days in making the journey from Quivira."* From Cicuyé he journeyed to Tiguex, where he went into winter quarters, with the intention in the spring of pursuing his discoveries by pushing his whole army toward Quivira.

"When winter was over Coronada ordered the preparation to be made for the march to Quivira. Every one then began to make his arrangements. Nevertheless, as often happens in the Indies, things did not turn out as people intended, but as God pleased. One day of festival the general went forth on horseback, as was his custom, to run at the ring with Don Pedro Maldonado. He was mounted on an excellent horse, but his valets having changed the girth of his saddle and having taken a rotten one, it broke in mid-course and the rider unfortunately fell near Don Pedro, whose horse was in full career, and in springing over his body kicked him in the head, thus inflicting an injury which kept him a long while in bed and placed him within two fingers of death."†

The result of this was that being of a superstitious nature and having been foretold by a certain mathematician of Salamanca, who was his friend, that he should one day find himself the omnipotent lord of a distant country, but that he should have a fall which would cause his death, he was very anxious to hasten home to die near his wife and children. From this time, Castañeda states, that Coronado, feigning himself to be more ill than he was, worked upon his soldiery in so subtle a way as to induce the greater part of them to petition him to return to New Spain. They then began openly to declare their belief that it was better to return, inasmuch as no rich country had been found, and it was not populous enough to distribute it among the army. The general, finding no one to oppose him, took up his line of march on his return to

This was, undoubtedly, the place in latitude 31° 39′, where the Rio del Norte, cutting through the mountains, empties into a deep and impassable cañon, from which it emerges some distance below, as has been before stated." (See Transactions of American Ethnological Society, vol. ii, p. 71.)

Mr. Gallatin, though usually very judicious in his remarks, I think is at fault here. The cause of the river disappearing at the point referred to, and then appearing again further down, was not on account of its entering a cañon, which the Spaniards could have noticed and not been deceived about, but because the Rio Tiguex, (Rio Grande,) like most of the rivers which I have seen on the plains and in New Mexico, is liable, when very low, to be lost in its sandy bed, and then to appear again further down, where the sand is not sufficient to absorb it. It is on this account, as I have seen, when the heat of the sun added its potent influence to cause a river to disappear through the day, that during the night, when this influence did not prevail, it would again appear a running stream.

Humboldt refers to a disappearance of the Rio Grande, which appears to have taken place about the same locality, and also attributes it to a wrong cause. "The inhabitants of Paso del Norte preserve the memory of a very extraordinary event which occurred in the year 1752. They saw, all at once, the river become dry, thirty leagues above, and more than twenty leagues below, El Paso; the water of the river precipitated itself in a newly-formed crevasse, and did not appear again above ground until you reach the Presidio de San Elezario." (Humboldt's Essai Politique Sur le Royaume de la Nouvelle Hispagne, edition 1811, p. 303.)

* Castañeda's Relations, Ternaux Compans, p. 142.

† Castañeda's Relations, Ternaux Compans, p. 202.

Mexico in the beginning of April, 1542. He returned by the way of Cibola and Chichilticale, as he had come. At length, after skirmishing with the Indians, in which a number of their men and horses were killed, the army reached Culiacan. From this place Coronado departed for the city of Mexico, to make his report to the viceroy, only about one hundred of his army continuing with him. "Castañeda says he was badly received by the viceroy, who nevertheless gave him a discharge; yet he lost his reputation and soon after his government of New Galicia also."*

Thus ended this great expedition, which for extent in distance traveled, duration in time, extending from the spring of 1540 to the summer of 1542, or more than two years, and the multiplicity of its coöperating branch explorations, equaled, if it did not exceed, any land expedition that has been undertaken in modern times.

Having given a general account of the routes pursued by Coronado and his army and of the track of the transport vessels under Alarcon, I will now proceed to fix definitely, so far as I have been enabled, the position of the several important places mentioned by Castañeda and other chroniclers.

The first important point after leaving the city of Mexico is Compostella, where the army rendezvoused preparatory to its setting out on its expedition. This point reached, the army, in an organized condition, took up its line of march along the foot of the west base of the Sierra Nevada in the direction, west of north, as far as Sonora, on the Sonora River; from this place its course was most probably more directly towards Chichilticale, or northerly, through the mountains, as far as the plains of the lower portion of the Rio Santa Cruz, over which it continued its march to Chichilticale.

The towns of Compostella, Culiacan, Cinaloa, and Sonora, points of the routes, are laid down from the "military map of the United States," recently issued from the office of the Chief of Engineers United States War Department. The other points are laid down from data obtained as follows: Chiametla, from "American Atlas, by Mr. Thomas Jeffreys, London, A. D. 1775;" Petatlan, 30 leagues north of Culiacan according to Castañeda,† and four days' journey according to Jaramillo.‡

With regard to the position of the town of Corazones, it is difficult, on account of the vagueness of the narratives of Jaramillo and Coronado, to fix it. Jaramillo speaks of it as having been situated about five days' journey northwardly from the Yaquemi River, and conveys the idea that it was near or on the Rio Sonora.§ Castañeda says, "in the lower part of the valley of Sonora is that of the Corazones, inhabited by Spaniards."‖ Again, "Don Tristan decided to found and colonize a town called San Hieronimo de los Corazones; but seeing that it could not prosper in this valley, he transferred it to a place called Senora,

* Castañeda's Relations, Ternaux Compans, p. 227. Gomora says, "It grieved Don Antonio de Mendoça very much that the army returned home, for he had spent about three-score thousand *pesos* of gold in the enterprise and owed a great part thereof still. Many sought to have dwelt there, but Francisco Vasquez de Coronado, who was rich and lately married a fair wife, would not consent, saying that they could not maintain nor defend themselves in so poor a country and so far from succor. They traveled about 900 leagues in this country." (The rest of the voyage to Acuco, Tiguex, Cicuic, and Quivira, from the General History of the West Indies, by Francis Lopez de Gomora, as quoted by Hakluyt, vol. iii.)

† Castañeda's Relations, Ternaux Compans, p. 223.

‡ Jaramillo's Relations, p. 365.

§ Jaramillo's Relations, Ternaux Compans, p. 366.

‖ Castañeda's Relations, p. 157.

(Sonora,) and it has been so called to this day."* Again, in another part of his Relations, describing the places between the Sonora River and Chichilticale, he informs us that "it was forty leagues from Sonora to the valley of the Suya, where was founded the city of San Hieronimo."† Now, my idea is, that the town of Corazones on the Sonora River was Sonora, so called because it was eminently the town of the province of Corazones, in which it was situated; and that San Hieronimo de los Corazones was situated, according to Coronado, ten or twelve leagues from the sea,‡ and, as above stated, forty leagues from Sonora, on the Suya River; which would place it about where I have located it, on a river which is now called the San Ignacio.†

From Sonora the march was, according to Jaramillo, four days to the Nexpa River. Jaramillo says: "After leaving Sonora we made a journey of four days in a desert, and arrived at another stream, which we understood was called Nexpa. We descended the stream two days, and we quitted it to the right at a foot of a chain of mountains, which we followed two days. They told us that it was called Chichilticale. After having left the mountains we came to a deep creek, the banks of which were escarped. After quitting this stream, which is beyond the Nexpa of which I have spoken, we took a northeast direction," &c.‖

Now the Nexpa, the stream they descended two days, I believe was the Santa Cruz, running in a northerly direction, (the proper direction of their march;) the mountains, at the foot of which they also traveled two days, were the "Santa Catarina Mountains;" and the stream which they then reached was the Gila, whose deep bed and escarped banks so exactly correspond with the description given by Jaramillo.¶

The next important place was Chichilticale. Here was the Casa Grande of which so much had been reported, and here the army commenced its march northeastwardly across the great desert, on the far side of which were the seven cities of Cibola. That the Casa Grande was so situated, with regard to Cibola, there is no dispute; but of its exact location there is some question.

Castañeda says: "At Chichilticale the country ceases to be covered with thorny trees, and changes its aspect; it is there the gulf terminates, and the coast turns *(C'est là que le golfe se termine et que la côte tourne;)* the mountains follow the same direction, and they must be crossed to reach the plains again."**

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* Castañeda's Relations, p. 44. † Ibid., p. 158.

‡ The sea (Gulf of California) returneth towards the west, right against the Corazones, the space of ten or twelve leagues. (Coronado's Rel., Hakluyt, vol. iii, p. 448.)

§ In this connection it may be pertinent to remark, that San Hieronimo de los Corazones, which seems to have been a sort of depôt, was transferred to Sonora; but appears still to have been kept as a post, for we are told that some of its garrison deserted it, for, among other reasons, that they looked on it as useless, "for the road to New Spain passed by a more favorable direction, leaving Suya to the right." This will account for two routes being laid down on the accompanying map between Sonora and the Nexpa River.

‖ Jaramillo's Relations, Ternaux Compans, pp. 367 and 368.

¶ Mr. E. G. Squier supposes the Nexpa to have been the Rio Gila. His language is: "Allowing 30 miles to the day's march, which is about the average under favorable circumstances, we have 120 miles as the distance between the point on the Sonora River left by Coronado in his advance and Chichilticale, between longitudes 109° and 110°. This is, according to the best maps, about the distance between the Sonora River and the Gila, called Nexpa by the chronicler." (American Review for November, 1848, p. 6.)

I cannot agree with Mr. Squier in the foregoing statement, for the reason that the distance between the Sonora River and the Gila, according to the latest map issued by the Engineer Department of the Army, is not 120 miles, but as much as 290 miles; and, therefore, as many as eight or ten days' journey instead of four.

** Castañeda's Relations, Ternaux Compans, p. 160.

Now this certainly shows that Castañeda believed Chichilticale was situated at the head of the Gulf of California. But according to Coronado's report to the viceroy Mendoça, this assuredly was not the case; for he says: "I departed for the Corazones, and always kept by the sea-coast as near as I could judge, and, in very deed, I still found myself the farther off, in such sort that, when I arrived at Chichilticale, I found myself ten days' journey from the sea, and the father provincial (Marcos de Niça) said that it was only five leagues distant, and he had seen the same. We all conceived great grief, and were not a little confounded, when we saw that we found everything contrary to the information which he had given to your lordship."*

In another place, Coronado states that the transport ships which had been ordered to coöperate with him had been seen off the country of the Corazones, on their way to "discover the haven of Chichilticale, which Marcos de Niça said was in five-and-thirty degrees."†

The above certainly shows that both De Niça and Castañeda at one time believed that Chichilticale was at the head of the gulf; and it is probable that both the transport vessels and army were ordered to communicate with each other at that point, on the supposition that it was a good harbor, and would be a capital place for a depot of supplies before entering the great desert. But Coronado's report effectually explodes the idea of its having been found such; and if there were more proof on this point needed, it would appear in the fact that neither Alarcon, who commanded the fleet and passed up the Colorado River in search of the army, nor Melchior Diaz, who explored all around the head of the gulf, make any mention of having seen the place, which they most assuredly would have done had they passed anywhere near it.

But where was the exact location of Chichilticale? In my opinion it was on the Rio Gila at Casa Grande, in latitude 33° 4′ 21″ north, and longitude 111° 45′ west from Greenwich, and the following are my reasons therefor:

It is distinctly stated by Castañeda that the place was marked by a Casa Grande, which, though then in ruins on account of having been destroyed by the natives, had evidently been used as a fortress; that it had been built of red earth, and was evidently the work of a civilized people who had come from a distance.‡

Now, the first ruin to be seen on the Gila, ascending it from its mouth, and the only one along its whole course which bears any resemblance to that mentioned by Castañeda, and of which we have any record, is that described by Father Font, who, with Father Garces, saw it in 1775,

* Hakluyt's Voyages, vol. iii, p. 448. † Ibid.

‡ Castañeda's Relations, pp. 40, 161, 162. Mr. Morgan, in a foot-note to his paper before referred to, says: "There is no ruin on the Gila at the present time that answers the above description," and seems to have come to this conclusion, because Captain A. R. Johnston, United States Army, in his journal, (U. S. Ex. Doc. No. 41, 1848, p. 596,) says, "The house was built of a sort of white earth and pebbles, probably containing lime." Emory merely says, "The walls were formed of layers of mud," (Thirtieth Congress, First Session, Ex. Doc. No. 7, p. 82;) and Bartlett in his Personal Narrative, p. 272, informs us that "The walls are laid with large square blocks, and the material is the mud of the valley mixed with gravel."

Mr. N. H. Hutton, civil engineer, assistant to Lieutenant Whipple, in his explorations for the Pacific Railroad in 1853–'54, and at present my assistant, assures me that he has seen the locality and the ruins, and that the Casa had evidently been built of the earth in the vicinity, which is of a reddish color, though in certain reflections of the same the building appeared whitish, on account of the pebbles contained in the mass. Castañeda in his Relations, p. 41, says: "Cette maison, construite en terre rouge;" and p. 161, "La terre de ces pays est rouge." In addition, what more natural than that Emory and Bartlett, finding the color of the building nothing different from that of the soil in that region, should fail to say anything about it?

on their journey to Monterey and the port of San Francisco, and which same ruin was subsequently visited and described by Emory, of the Corps of Topographical Engineers, in 1847.

Father Font's description of it is as follows:

"On the 3d of October, 1775, the commandant ordered us to halt, in order that we might visit the Casa Grande, known by the name of Montesuma, situated one league from the Rio Gila. We were accompanied by some Indians, and by the governor of Uturituc, who related to us on the way the tradition he had received from his ancestors about this house, some of the particulars of which are doubtless fabulous and others again true.

"The latitude of the locality we found by an observation of the sun to be 33½°.

"The Casa Grande, or palace of Montesuma, must have been built five hundred years previously, (in the thirteenth century,) if we are to believe the accounts given by the Indians; for it appears to have been constructed by the Mexicans at the epoch of their emigration when the devil, conducting them through different countries, led them to the promised land of Mexico. The house is seventy feet from north to south, and fifty from east to west.* The interior walls are four feet in thickness; they are well constructed; the exterior walls are six feet thick. The edifice is constructed of earth, in blocks of different thickness, and has three stories. We found no traces of stairways; we think they must have been burnt when the Apaches burnt this edifice."†

Emory's description, evidently of this same building—for the old maps place Father Font's Casa Grande on the Rio Gila, just above the Pima village, where Emory locates it—is as follows: "About the time of noon halt, a large pile which seemed the work of human hands was seen to the left. It was the remains of a three-story mud-house sixty feet square, pierced for doors and windows. The whole interior of the house had been burnt out, and the walls much defaced."‡

This description, though not precisely the same as that of Father Font, yet is sufficiently close, with the identity of the location, as before stated, to show that they have reference to the same building. Now, Emory by astronomical observation found the latitude of his camp near this locality to be 33° 4′ 21″ north, and the longitude west from Greenwich 111° 45′. Father Font, as before stated, determined the latitude to be 33½°; but as Emory had, without doubt, far superior instruments, his results are preferable.

We have then, as we think, located Chichilticale, the site of Casa Grande, with a strong probability of accuracy.

On Squier's map of Coronado's route, accompanying the paper on this subject, in the Transactions of the Ethnological Society, (vol. 2,) by Albert Gallatin, I perceive that he makes Coronado to cross the Gila at Casa Grande, but places the latter in about latitude 32°, and longitude 110°; or more than a degree too far south, and nearly two degrees too far to the east. Now, as Juan Jaramillo, who was a captain in Coronado's expedition, in his report says the general direction of their march from Chichilticale to Cibola was northeast,§ a line drawn from Chichil-

* A Spanish foot is 0.91319 of an English foot. (United States Ordnance Manual.)

† Journal of Father Font, of the college of Santa Cruz of Queretaro. Appendix VII. Casteneda's Relations, Ternaux Compans' Collections; see also Humboldt's "Essai Politique Sur la Royaume de la Nouvelle Espagne," edition of 1811, pp. 36, 297, 298.

‡ Notes of a military reconnoissance made by Lieutenant Colonel William H. Emory, Corps of Topographical Engineers, in 1846–'47, with the advance guard of the Army of the West, p. 82.

§ Juan Jaramillo's Relations, Ternaux Compans' Collections, pp. 368, 369.

ticale as laid down on Squier's map would not pass through or near Zuñi, (identical on his map with Cibola,) as it ought to do, but more than a degree to the east of it; thus showing his position of Chichilticale manifestly erroneous.

Again, on the map of R. H. Kern, accompanying "Schoolcraft's History of the Indian Tribes of North America," he places Chichilticale as much as a degree of latitude south of the Gila and in longitude 109°. Here again a line in a northeast direction from Chichilticale would not pass, as it should, through or near Zuñi, (identical, as Kern thinks, with Cibola,) but more than two degrees to the eastward of it; which also shows his position of Chichilticale very considerably out of the way.

The next and most important inquiry is the exact locality of the seven cities of Cibola. Gallatin, Squier, Whipple, Professor Turner, and Kern, have contended for Zuñi and its vicinity. Emory and Abert, on the contrary, have conjectured that Cibolletta, Moquino, Pojuati, Covero, Acoma, Laguna, and Poblacon, a group of villages some ninety miles to the eastward of Zuñi, furnish the site of the seven cities; and Mr. Morgan, as I have before remarked, in the North American Review for April, 1869, has advanced the idea that the ruins on the Chaco, lying about one hundred miles to the northeast of Zuñi, more completely satisfy all the conditions of the problem which the accounts of Coronado's journey, by Castañeda and others, have imposed on its solution. To my mind, however, Zuñi and vicinity present the strongest claims to being considered the site of the renowned cities, and the following are my reasons therefor:

It seems that from Chichilticale to Cibola, the direction of Coronado's route, according to Jaramillo, as before remarked, was generally northeast; and from Coronado's report I extract in relation to it as follows. He is speaking of what occurred after leaving Chichilticale:

"I entered the confines of the desert, on Saint John's day eve, and to refresh our former travels we found no grass, but worser way of mountains and bad passages where we had passed already; and the horses being tired were greatly molested therewith; but after we had passed these thirty leagues, we found fresh rivers and grasses like that of Castile, &c.; and there was flax, but chiefly near the banks of a certain river, which, therefore, was called El Rio del Lino, that is to say, the River of Flax; we found no Indians at all for a day's travel, but afterward four Indians came out unto us in peaceable manner, saying that they were sent over to that desert place to signify unto us that we were welcome."*

In addition to the foregoing, Castañeda says that in about fifteen days from Chichilticale "they arrived within eight leagues of Cibola, upon the banks of a river they called the Vermejo, on account of its red color;"† and Jaramillo remarks that in approaching Cibola "always in the same direction, that is to say, toward the northeast, they came to a river which they called the Vermejo; that here they met one or two Indians, who afterwards they recognized as belonging to the first village of Cibola; and that they reached this village in two days from when they had first met them."‡

Now let any one consult the accompanying map, reduced from the latest map issued by the Engineer Bureau at Washington, and he will

* Hakluyt's Voyages, vol. iii, p. 449.
† Castañeda's Relations, Ternaux Compans, p. 41.
‡ Jaramillo's Relations, Ternaux Compans, p. 369.

see that Coronado's march from Chichilticale, or Casa Grande, must have been very nearly coincident with the route there laid down, to wit: in a *northeasterly* direction for the first thirty leagues, over the rough Pinal and Mogollon Mountains; and then getting on the tributaries of the *Rio del Lino*, or Flax River, where he found "fresh water and grasses," he followed up the Vermejo, or Colorado River, to Cibola, or Zuñi of the present day and its vicinity, where he found the other six cities. The distance by such route, between Chichilticale and Zuñi, would be about 270 miles, or require a journey of 17 days, (about 16 miles a day,) the time it took Coronado to accomplish the distance;* and this agrees quite exactly with the distance, 80 leagues, as given by Castañeda in another place †

But there are other good reasons for this belief. At Zuñi and its vicinity, within a distance of about 16 miles, and on the banks of the Vermejo, or Little Colorado River, there are the ruins of as many as six pueblos, all showing that they were once built of stone; and, with the present Zuñi, doubtless they constituted the "seven cities" which, according to Coronado, were all built "within four leagues together,"‡ and according to Castañeda were "situated in a very narrow valley between *des Montagnes Escarpées*,"§ which may have been intended to mean escarped *mesas*, or table lands, just as close in the valley of the Little Colorado or Rio de Zuñi.

In my report to the Chief of Topographical Engineers of my reconnoissance made in the Navajo country in 1848, I described Zuñi as follows: "The pueblo of Zuñi, when first seen about three miles off, appeared like a low ridge of brownish rocks, not a tree being visible to relieve the nakedness of its appearance. It is a pueblo or Indian town, situated on the Rio de Zuñi. This river at the town has a bed of about 150 yards wide. The stream, however, at the time we saw it, only showed a breadth of about 6 feet and a depth of a few inches. It is represented as running into the Colorado of the West. The town, like Santo Domingo, is built terrace-shaped, each story—of which there are generally three—as you ascend being smaller laterally, so that one story answers, in fact, for the platform of the one above it. It, however, is far more compact than Santo Domingo, its streets being narrow, and in places presenting the appearance of tunnels or covered ways, on account of the houses extending at these places over them."‖

Lieutenant A. W. Whipple, Corps Topographical Engineers, visited the ruins of old Zuñi in 1853–'54, and in his report to the War Department thus describes the place: "We took a trail and proceeded two miles south to a deep cañon, where were springs of water. Thence by a zigzag course we led our mules up the first bench of ascent. At various points of the ascent, where a projecting rock permitted, were barricades of stone walls, from which, the old man (his guide) told us, they had hurled rocks upon the invading Spaniards. Having ascended, according to our estimate, 1,000 feet, we found ourselves upon a level surface covered with thick cedars. The top of the *mesa* was of an irregular figure a mile in width, and bounded on all sides by perpendicular cliffs. Three times we crossed it, searching in vain for the trace of a

* Castaneda's Relations, pp. 41, 42.

† Ibid., p. 188.

‡ Coronado's Relations, Hakluyt, vol. iii, p. 451.

§ Castañeda's Relations, Ternaux Compans, p. 164.

‖ "Journal of a military reconnoissance from Santa Fé, New Mexico, to the Navajo country, made by Lieutenant J. H. Simpson, Corps of Topographical Engineers, in 1849," United States Senate Ex. Doc. No. 64, 31st Congress, 1st session, 1850; also, Lippincott, Grambo & Co., Philadelphia, 1852, pp. 89 and 90.

ruin. But the guide hurried us on half a mile further, when appeared the ruins of a city indeed. Crumbling walls from 2 to 12 feet high were crowded together in confused heaps over several acres of ground. Upon examining the pueblo we found that the standing walls rested upon ruins of greater antiquity. The primitive masonry, as well as we could judge, must have been about 6 feet thick. The more recent was not more than a foot, but the small sandstone blocks had been laid in mud mortar with considerable care."*

Now I take it that old Zuñi was one of the seven towns of Cibola, called by Coronado "Grenada, because it was somewhat like to it;"† and the *narrow winding way*, ascending which Coronado was knocked down by stones hurled upon him by the defenders,‡ was in all probability the very zigzag approach mentioned by Whipple, and which he found so difficult in his ascent to the ruins.

The other six towns were doubtless Zuñi of the present day, and those whose ruins are to be found still further up the valley, showing they had been stone structures, and to which I refer in my report before referred to, as follows: "Within a few yards of us are several heaps of pueblo ruins. Two of them, on examination, I found to be of elliptical shape and approximating 1,000 feet in circuit. The buildings seem to have been chiefly built on the periphery of an ellipse, having a large interior court; but their style and the details of their construction, except that they were built of stone and mud mortar, are not distinguishable in the general mass. The areas of each are now so overgrown with bushes and so much commingled with mother earth as, except on critical examination, to be scarcely distinguishable from natural mounds. The usual quantum of pottery lies scattered around. The governor of Zuñi, who is again on a visit to us, informs us that the ruins I have just described, as also those seen a couple of miles back, are the ruins of pueblos which his people formerly inhabited."§

There are other circumstances of relative position of places which point most indubitably to the same conclusion, as follows: Castañeda repeatedly states that Cibola was the *first* inhabited province they met going north from Chichilticale *after* they crossed the desert, and the *last* they left *before entering* the desert on their return to Mexico. Again, the present relations to each other of Zuñi and the Moqui Pueblos, and also of Acoma, perched on a mesa height, in regard to courses and distances tally sufficiently near with the positions of Tusayan and Acuco, as given by Castañeda, namely, the former northwest 25 leagues and the latter eastwardly five days' journey from Cibola,‖ as to make it exceedingly probable that they refer to the same localities.¶ Again, Castañedo,

* Pacific R. R. Reports, vol. iii, pp. 68, 69.

† Coronado's Relation, Hakluyt, vol. iii, p. 451.

‡ "Cependant il fallait s'emparer de Cibola ce qui n'était pas chose facile, car le chemin qui y conduisaat était étroit et tortueux. Le Général fut renversé d'un coup de pierre en montant à l'assaut," &c. Castañeda's Rel., Ternaux Compans, p. 43.

§ Simpson's Journal, p. 97.

‖ Castañeda's Relations, Ternaux Compans, pp. 58, 67, 68, 69, 70, 165.

¶ Mr. Squier, in his article on the "Ancient Monuments, &c., in New Mexico and California," in American Review for November, 1848, gives the position of Tusayan from Cibola, *both* northeast and northwest from Cibola, and on his map accompanying Mr. Albert Gallatin's Essay, in the Transactions of the American Ethnological Society, vol. ii, he has placed it in a northeast direction. The proper direction of Tusayan with regard to Cibola is northwest. (See Castañeda's Relations, Ternaux Compans, p. 165.) Besides Cardenas, on his way to the Rio del Tizon, (Colorado,) passed through Tusayan from Cibola, which makes it all very natural if Tusayan was northwest from Cibola, but would not be so if it was in a northeast direction, as laid down on Mr. Squier's map.

describing the valley in which the province of Cibola was situated, says, "Cest une vallée trés-etroite entre des montagnes escarpées,"* which is an exact description of the valley of the Rio de Zuñi, confined between the walls of inclosing mesas. Again, Jaramillo says "this first village of Cibola is exposed a little towards the northeast, and to the northwest in about five days' journey is a province of seven villages called Tusayan,† all of which exactly accords with the exposed position to the northeast of old Zuñi and correctly describes the location of the Moqui villages.

But there is some historical evidence upon this point which I consider irrefragable, and which certainly makes Zuñi and Cibola identical places.

Referring to the relation of a notable journey made by Antonio de Espejo to New Mexico, in 1583, to be found in Hakluyt's Voyages, vol. iii, I read as follows: "Antonio de Espejo also visited Acoma, situated upon a high rock which was about 50 paces high, having no other entrance but by a ladder or pair of stairs hewn into the same rock, whereat our people marveled not a little.

"Twenty-five leagues from hence, toward the west, they came to a certain province called by the inhabitants themselves Zuñi, and by the Spaniards Cibola, containing a great number of Indians, in which province Francisco Vasquez de Coronado had been, and had erected many crosses and other tokens of Christianity, which remained as yet standing. Here also they found three Indian Christians who had remained there ever since the said journey, whose names were Andrew de Culiacan, Gaspar de Mexico, and Antonio de Guadalajara, who had about forgotten their language, but could speak the country speech very well; howbeit after some small conference with our men they easily understood one another."

Now turning to Castaneda's Relations, where he gives an account of Coronado's leaving the country for Mexico, I find his language as follows: "When the army arrived at Cibola it rested for a while to prepare itself for entering the desert, for it is the last point inhabited. We left the country entirely peaceful; there were some Indians from Mexico who had accompanied us, who remained there and established themselves, (il y ent même quelques Indiens du Mexique qui nous avaient accompagnés, qui y restèrent et s'y établirent.")‡

Thus it would seem that the two accounts of Espejo and Castañeda correspond in such a manner as not to leave the slightest doubt that Zuñi of the present day is the Cibola of old. Coronado left three of his men at Cibola, who were found living there by Espejo and his party forty years afterwards; they had nearly forgotten their original language, but yet, after awhile, managed to converse with some of Espejo's men. What more natural, and, indeed, what could have been a more interesting topic than the adventures of these men; how they got there, and whether Zuñi was veritably the far-famed Cibola that forty years previously had excited the attention of the governments of New and Old Spain. Espejo, under the above circumstances, reporting that the Spaniards called Zuñi Cibola, certainly could not have meant anything else than that he believed it veritably such. I have been thus particular with regard to this testimony, for the reason that Mr. Morgan, in his essay already referred to, while he recognizes the historical fact of Zuñi having been called by the Spaniards, according to Espejo's Relations, Cibola, in 1583, yet advances the idea that after all Espejo probably

* Castañeda's Relations, Ternaux Compans, p. 164.
† Jaramillo's Relations, Ternaux Compans, p. 370.
‡ Castañeda's Relations, Ternaux Compans, p. 217.

only meant to express that they conjectured the places to have been identical.

It seems to me that what I have advanced shows most conclusively that Cibola and Zuñi are identical localities, and nothing could be said which could make it more certain; but as corroborative I will state that I have seen in the excellent library of the Peabody Institute of Baltimore an atlas entitled "The American Atlas, or a Geographical Description of the whole Continent of America, by Mr. Thomas Jeffreys, Geographer, published in London in 1773." On map No. 5 of this atlas, Zuñi and Cibola are laid down as synonymous names, and the locality they express is precisely that of Zuñi of the present day.* Again, on a "Carte contenant le Royaume du Mexique et La Floride," in the "Atlas Historique par Mr. C * * * avec des dissertations sur l'Histoire de chaque etat par Mr. Guendeville," tome vi, second edition, published in Amsterdam, 1732, I find Zuñi and Cibola laid down as synonymous.

In this connection it may be proper to observe that the claims of Ciboletta, Moquino, Poquate, Covero, Acomo, Laguna, Poblacon, as conjectured by Emory and Abert to be regarded as the seven cities of Cibola, are rendered null by the historical fact mentioned by Castañeda, and also by Jaramillo, that the latter were situated on the Rio Vermejo, (Little Colorado,) a tributary of the Southern Ocean;† and also by the circumstance of the army, on its march from Cibola to Tiguex, finding Acuco (Acoma) five days' journey to the eastward of Cibola, a circumstance which could not have taken place if Acuco (Acoma) were one of the seven towns of Cibola. Besides, Castañeda, in enumerating the villages dispersed in the country, expressly states that "Cibola is the first province; it contains seven villages; Tusayan, seven; the rock of Acuco, one, &c.,‡ which certainly shows that Cibola and Acuco were separate and district provinces.

Again, I cannot see that the ruins of the Chaco, which, according to my explorations and reading are probably, on account of their extent and character, the most remarkable yet discovered in this country, have any just claims, as advanced by Mr. Morgan, to be regarded as the seven cities of Cibola;§ first, for the reason that they are not, as required by historical fact, situated on the Rio Vermejo, (Little Colorado,) or tributary of the Rio del Lino or Flax River; second, they are not so situated with regard to the desert passed over by Coronado, between Chichilticale and Cibola, as to make the statement of Castañeda pertinent, to wit,

* On this atlas is indorsed, "Presented to the Peabody Institute by the Hon. John P. Kennedy, April 1, 1864. By this map the great dispute between Daniel Webster and Lord Ashburton (relating doubtless to the northeastern boundary) was settled, particularly by map No. 5."

† "All the streams we met, whether rivulet or river, as far as that of Cibola, and I believe even one or two days' journey beyond that place, flow in the direction of the South Sea, (Mer du Sud,) meaning the Pacific Ocean;" further on they flow to the North Sea, (Mer du Nord,) meaning the Gulf of Mexico. Jaramillo's Relations, Ternaux Compans, p. 370.

‡ Castaneda's Relations, Ternaux Compans, pp. 181, 182.

§ Mr. Morgan, in his essay before referred to, having already made large extracts from my report to the Government on these ruins, I deem it unnecessary to say anything further in relation to them than to refer the reader for a more detailed account to said report. It is interesting, however, in this connection, to present the following extract from Humboldt's Essai sur le Royaume de la Nouvelle Espagne, page 305, which in all probability refers to these very ruins: "The Indian traditions inform us that some twenty leagues to the north of Moqui, near the embouchure of the river Zejuannes, a river of the Navajos, was the first resting place (*demeure*) of the Aztecs after their sortie from Atzlan." Again, on his map accompanying his Essay, is the following: "Premiere demeure des Azteques sortés d'Atzlan en 1160, tradition in certaine," in longitude about 112°30″, latitude 37°.

that Cibola was the first village to be met after passing the desert, and the last on leaving the peopled country to enter the desert; third, the Moqui villages (undoubtedly Tusayan) do not lie to the northwest from the ruins on the Chaco, as they should do if these ruins were Cibola, but to the south of west; and fourth, the route of Coronado's army eastward from there to Cicuyé, by the way of Acuco, (Acoma,) would have been very much and unnecessarily out of the proper direction.

Mr. Morgan mentions the fact stated by Coronado, that it was eight days' journey from Cibola to the buffalo range. This, he thinks, could very well have taken place on the hypothesis of the Chaco ruins having been Cibola, but not on the supposition of Zuñi. But the distance of Zuñi to the buffalo range east of the Rio Pecos is only about 230 miles, which certainly could have been reached in eight days, allowing the journey he does of 30 miles per day.

But to proceed with the principal points of Coronado's route eastward from Cibola. I believe that all authorities who have written on the subject concur in the view that the Pueblo of Acoma, or Hak-koo-kee-ah, as it is now called in the Zuñi language, is the Acuco of Colorado.* The singular coincidence of the names, as well as the striking resemblance of the two places as described by Castañeda and Abert, which cannot be predicated of any other place in New Mexico, together with the proper relation of Acoma to Zuñi (Cibola) and Tiguex in distance and direction, all show that they are identical.†

The next province Coronado entered was that of Tiguex. Mr. Gallatin has located it on the Rio Puerco. His language relating to it is as follows: "Having compared those several accounts (of Castañeda and Jaramillo) with Lieutenant Abert's map and with that of Mr. Gregg, it

* Lieutenant Colonel J. H. Eaton, United States Army, writing on this subject, remarks: "In a conversation with a very intelligent Zuñi Indian I learned that the Pueblo of Acoma is called in the Zuñi tongue Hak-koo-kee-ah, (Acuco,) and this name was given to me without any previous question which would serve to give him an idea of this old Spanish name. Does not this, therefore, seem to give color to the hypothesis that Coronado's army passed by or near to the present Pueblo of Zuñi, and that it was their Cibola, or one of the seven cities of Cibola." (Schoolcraft's History of the Indian Tribes of the United States, part iv, p. 220.)

† The following graphic description of Acoma is from Abert: "After a journey of 15 miles we arrived at Acoma. High on a lofty rock of sandstone, such as I have described, sits the city of Acoma. On the northern side of the rock the rude boreal blasts have heaped up the sand so as to form a practical ascent for some distance; the rest of the way is through solid rock. At one place a singular opening or narrow way is formed between a huge, square tower of rock and the perpendicular face of the cliff. Then the road winds round like a spiral stairway; and the Indians have, in some way, fixed logs of wood in the rock, radiating from a vertical axis, like steps. These afford foothold to man and beast in clambering up.

"We were constantly meeting and passing Indians, who had their 'burros' laden with peaches. At last we reached the top of the rock, which was nearly level, and contains about sixty acres. Here we saw a large church, and several continuous blocks of buildings, containing sixty or seventy houses in each block. (The wall at the side that faced outward was unbroken, and had no windows until near the top. The houses were three stories high.) In front, each story retreated back as it ascended, so as to leave a platform along the whole front of the story. These platforms are guarded by parapet walls about three feet high. In order to gain admittance you ascend to the second story by means of ladders. The next story is gained by the same means; but to reach the 'azotia,' or roof, the partition walls on the platform that separates the quarters of different families have been formed into steps. This makes quite a narrow staircase, as the walls are not more than one foot in width." (Report of Lieutenant J. W. Abert, Corps Topographical Engineers, of his examination of New Mexico in the years 1846-'47, Ex. Doc. 41, 30th Congress, 1st session, pp. 470, 471.)

appears to me probable that the Tiguex country lay, not on the main Rio Norte, but on its tributary, the Rio Puerco and its branches, and that the river which the Spaniards called Cicuyé, and on which they were obliged to build a bridge, was the main Rio del Norte."*

Mr. W. H. Davis, author of "El Gringo; or New Mexico and her People," published in 1853, takes the same view.

Mr. Squier believes the Rio de Tiguex to have been the Rio Grande, and the Rio de Cicuyé the Pecos, but locates Tiguex on the Rio Grande, *above* the mouth of the Puerco. Messrs. Kern and Morgan take the same view.

According to my investigations I believe the Rio Tiguex to have been the Rio Grande, and the Rio de Cicuyé the Rio Pecos; but while I am willing to admit there are some grounds for the hypothesis that Tiguex was located on the Rio Grande *above* the mouth of the Puerco, yet I think there are still stronger grounds for the belief that it was situated on the Rio Grande *below* that river.

Castañeda says, "Three days' journey from Acuco (Acoma) Alvarado and his army arrived in a province which was called Tiguex."†

Again, "The province of Tiguex contains twelve villages, situated on the banks of a great river in a valley about two leagues broad. It is bounded on the west by some mountains, which are very high and covered with snow. Four villages are built at the foot of these mountains and three others upon the heights."‡

Now, as Coronado and his army marched eastward § from Acuco, (Acoma,) and they accomplished the distance in a three days' journey and then came to a large river, on the banks of which was situated the province of Tiguex, it is clear that as the Rio Grande is the first large river to be met eastward from Acuco (Acoma) at a distance varying from sixty to eighty miles, depending on the route taken, this was the great river referred to, or the Rio de Tiguex.

The idea of Mr. Gallatin and Mr. Davis that the Puerco was this river is, I think, entirely untenable, for the reason that this river in its best stage is only about one hundred and twenty miles long, and frequently, as I myself have observed, so dry that its existence could only be inferred from its dry bed and the occasional pools of water to be met along its track. It certainly, then, could not with any propriety be called a *great* river, as the Rio de Tiguex was represented to be.

In addition, we learn that the guides who conducted the army back to Cicuyé, on its return from its search after Quivira, declared that the Rio de Cicuyé threw itself into the Rio de Tiguex more than twenty days' journey (or over four hundred miles) below where they struck it;"‖ which would have been an absurdity if the Tiguex were the trifling Rio Puerco, and the Cicuyé the Rio Grande, as Mr. Gallatin supposed; but which is all very plain on the hypothesis that the Tiguex was the Rio Grande, and the Cicuyé the Pecos.

But where was the exact location of the province of Tiguex?

It was certainly *below* Hemez and Quirix, (San Felipe,¶) for the chron-

* Transactions American Ethnological Society, vol. 2, p. 73.

† Castañeda's Relations, Ternaux Compans, p. 71.

‡ Castañeda's Relations, Ternaux Compans, pp. 167, 168.

§ Ibid, p. 67.

‖ Castañeda's Relations, Ternaux Compans, p. 135.

¶ On the old maps, as also on Humboldt's, illustrating his "Nouvelle Hispagne," I notice the pueblo of San Felipe is laid down as "S. Felipe *de Cueres*," which I am informed is its name at this day. Indeed, Gregg, speaking of certain pueblos in New Mexico, says, "those of Cochiti, Santo Domingo, San Felipe, and perhaps Sandia, speak the same tongue, though they seem formerly to have been distinguished as Queres." (Commerce of the Prairies, 2d edition, vol. i, p. 269.)

ider states that farther to the north (from Tiguex) is the province of Quirix, which contains seven villages; seven leagues to the northwest (which may mean from Quirix or Tiguex) that of Hemez, which contains the same number, &c.;* the text says, "nord-est," but this is evidently a mistake, as the oldest maps extant place Hemez where it is now situated, on the Rio de Hemez, to the west of the Rio Grande.

The foregoing would seem to show conclusively that Tiguex was situated below Quirix, and possibly, under one of the constructions given above, only seven leagues or twenty-four miles below Hemez, which would place it on the Rio Grande just about the mouth of the Rio de Hemez, or about 80 miles above the mouth of the Puerco, where the authorities above given have placed it. But yet the extract before given from Castañeda expressly states also that the "Province of Tiguex was situated upon the banks of a great river (Rio de Tiguex) in a valley about two leagues broad, and bounded on its west by some very high, snowy mountains," &c. Now, the only locality which will answer this description is that part of the valley of the Rio Grande bounded on its west by the Socorro Mountains, situated just below the mouth of the Puerco. These are the first mountains to be met in descending the river from Santo Domingo, or from even above that pueblo, (all the intervening heights being merely table-lands and therefore not so elevated as to be termed snowy,) and they fix the locality, in my judgment, as I have before stated, *below* the mouth of the Puerco.

I have, therefore, on my map located the province of Tiguex on the Rio Grande below the Rio Puerco, at the foot of the Socorro Mountains, which bounds it on its west; and it is somewhat confirmatory of this position that on the map No. 5 of "Thomas Jeffreys' Atlas," before referred to as excellent authority, I find *Tigua*, no doubt intended for the same place, or province, located in the valley of the Rio Grande, just where I have located Tiguex, namely, at the foot of the Socorro Mountains.

The next important place in the route of Coronado from Tiguex was Cicuyé. Castañedo says: "After a journey of five days from Tiguex, Alvarado (with his detachment of twenty men) arrived at Cicuyé, a very well fortified village, the houses of which are four stories high."† Again, "The armyquitted Tiguex on the 5th of May (1531) and took the route to Cicuyé, which is twenty-five leagues distant."‡ Jaramillo states the direction to have been "northeast."§ In another place Castañeda remarks that "Cicuyé is built in a narrow valley, in the midst of mountains covered with pines. It is traversed by a small stream, in which we caught some excellent trout."||

Now, all this points, as I believe, to the ruins of Pecos, on the Rio Pecos, as the site of Cicuyé, and in this I agree with Mr. Squier and Mr. Kern. These ruins are in a northeast direction from the supposed position of Tiguex, and about five days' journey distant. They are also situated in a narrow valley in the midst of mountains covered with pines, and the site is traversed by a small silvery stream, in which may be caught some excellent trout. I certainly know no other place that in so many respects suits the conditions of the problem; but the

* Castañeda's Relations, Ternaux Compans.
† Castañeda's Relations, Ternaux Compans, p. 71.
‡ Castaneda's Relations, Ternaux Compans, p. 113.
§ Jaramillo's Relations, Ternaux Compans, p. 371.
|| Castañeda's Relations, Ternaux Compans, p. 179.

Coronado's description of the region is as follows: "The province of Quivira is 950 leagues (3,230 miles) from Mexico. The place I have reached is the 40° of latitude. The earth is the best possible for all kinds of productions of Spain, for while it is very strong and black, it is very well watered by brooks, springs, and rivers. I found prunes like those of Spain, some of which were black, also some excellent grapes and mulberries."*

Jaramillo, who accompanied Coronado to Quivira, speaking of this region, says: "This country (Quivira) has a superb appearance, and such that I have not seen better in all of Spain, neither in Italy nor France, nor in any other country where I have been in the service of your Majesty. It is not a country of mountains; there are only some hills, some plains, and some streams of very fine water, (des ruis-seaux de fort belle eau.) It satisfied me completely. I presume that it is very fertile and favorable for the cultivation of all kinds of fruits."†

In another portion of his Relations he mentions having crossed a large river, to which they gave the name of "Saint Peter and Saint Paul," which very probably was the Arkansas, and after traveling several days farther north, they came to the province of Quivira, where they learned that there was a still larger river farther on, to which they gave the name of "Teucarea," and which I believe to have been the Missouri.‡

Again, Castañeda says: "It is in this country (that of Quivira) that the Espiritu Sancto, (Mississippi,) which Don Fernando de Soto discovered in Florida, takes its source. * * * * The course of this river is so long, and it receives so many affluents, that it is of prodigious length to where it debouches into the sea, and its fresh waters extend far out after you have lost sight of the land."§

All the authors who have written on this subject seem to have discredited Coronado's report that he explored northwardly as far as the 40° of north latitude; but not only do the reports of Castañeda and Jaramillo bear him out in his statement, but the peculiar description of the country as given by them all—namely, that it was *exceedingly rich;* its soil *black;* that it bore, spontaneously, grapes and prunes, (wild plums;) was watered by many streams of pure water, &c.; and the circumstance of this kind of country not being found anywhere in the probable direction of Coronado's route, except across the Arkansas and on the headwaters of the Arkansas River; all this, together with the allusion to a large river, the "Saint Peter and Saint Paul," (probably the Arkansas,) which they crossed before reaching Quivira, in lati-

* Following the orders of your Majesty (Don Antonio de Mendoça,) I have observed the best possible treatment toward the natives of this province, and of all others that I have traversed. They have nothing to complain of me or my people. I sojourned twenty-five days in the province of Quivira, as much to thoroughly explore the country as to see if I could not find some further occasion to serve your Majesty, for the guides whom I brought with me have spoken of provinces situated still farther on. That which I have been able to learn is, that in all this country one can find neither gold nor any other metal. They spoke to me of small villages, whose inhabitants for the most part do not cultivate the soil. They have huts of hides and of willows, and change their places of abode with the *vaches* (buffaloes.) The tale they told me then (that Quivira was a city of extraordinary buildings and full of gold) was false. In inducing me to part with all my army to come to this country, the Indians thought that the country being desert and without water, they would conduct us into places where our horses and ourselves would die of hunger; that is what the guides have confessed. They told that they had acted by the advice of the natives of these countries. (Coronado's Relations, Ternaux Compans, pp. 360, 361.)

† Jaramillo's Relations, Ternaux Compans, p. 378.

‡ Jaramillo's Relations, Ternaux Compans, pp. 375, 377.

§ Castañeda's Relations, Ternaux Compans, p. 195.

tude 40° north; and to a still larger river further on (probably the Missouri)—makes it exceedingly probable that he reached the fortieth degree of latitude, or what is now the boundary between the States of Kansas and Nebraska, well on towards the Missouri River; and in this region I have terminated his explorations north on the accompanying map.*

In regard to the *return* route of the army of Coronado, which he dispatched to Tignex before he reached Quivira, it is expressly mentioned that they passed by some salt ponds, and, as I believe they are only to be found in that region of country between the Canadian and Arkansas Rivers, on the Little Arkansas River, a tributary of the latter, in about latitude 37°, and longitude 99°, I have located this route as passing by these ponds, with some probability of its being correct.†

Another point of the return route of the army was where it struck the Rio Cicuyé, about thirty leagues below the bridge, where it had crossed it on their outward march.‡

Besides the provinces I have endeavored to locate there were a number, as I have already stated, visited by Coronado, or his officers, which were situated on the Rio Tiguex, (Rio Grande,) or some of its tributaries, as follows: Quirix, containing seven villages; in the Snow Mountains, seven; Ximena, three; Chea, one; Hemes, seven; Aguas Calientes, three; Yuque-yunque of the mountain, six; Valladolid or Braba, one; Tutahaco, eight.

Quirix was unquestionably *San Phelipe de Queres* of the present day; Chea, *Silla;* Hemes, *Hemez;* Aguas Calientes, *the ruins which I have seen at Ojos Calientes*, twelve miles above Hemez, on the Rio de Hemez; and Braba, *Taos*. The situation of all the places named accord so well with that given by Castañeda as to leave but little doubt that they are identical.

In addition, in relation to Braba, Castañeda states that it was the last town on the Rio Tiguex, north, and was "built on the two banks of a stream which was crossed by bridges built of nicely-squared pine timber." Gregg, speaking of Taos, which is the last pueblo on the Rio Grande north of Santa Fé, says: "There still exists a pueblo of Taos, composed for the most part of but two edifices of very singular construction, on each side of a creek, and formerly communicating by a bridge. The base story, near 400 feet long and 150 wide, is divided into numerous apartments, upon which other tiers of rooms are built, one above another, forming a pyramidal pile of fifty or sixty feet high, and comprising some six or eight stories."§ The identity, therefore, of the two places I think certain.

All the vilages along the Rio de Tiguex, (Rio Grande,) explored by Castañeda, were included in a district thirty leagues (102 miles) broad and one hundred and thirty (442 miles) long.

Castañeda, speaking of the origin of the people who inhabited these regions, says: "This circumstance, the customs and form of government

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* This hypothesis is also strengthened by the fact that the Turk who guided Coronado stated that he was "a native of the country on the side of Florida," that is, toward the east from the Rio Tiguex, (Rio Grande,) in the valley of which he was at that time; that in his country was "a river two leagues broad," &c.; and that when he reached Quivira he told the Spaniards "that his country was still beyond that." (See Castañeda's Relations, Ternaux Compans, pp. 72, 77, 131.)

† See ante, p. 40.

‡ Between the outward and return route the Canadian River is deeply cañoned for fifty miles, which doubtless necessitated the army on its return either to cross it where it did when going to Quivira, or at least fifty miles below that point; and doing the latter, it naturally struck the Pecos proportionally lower down from the bridge.

§ Gregg's Commerce of the Prairies, 2d ed., vol. ii, p. 277.

of these nations, which are so entirely different from those of all the other nations we have found up to the present time, prove that they came from the region of the Great India, whose coasts touch those of this country on the west. They may have approached by following the course of the river after crossing the mountains, and may have there fixed themselves in the locations that seemed most advantageous to them. As they multiplied they built other villages along the banks, until the stream failed them by plunging into the earth. When it reappears it flows toward Florida. It is said that there are other villages on the banks of this river, but we did not visit them, preferring, according to the Turk's advice, to cross the mountains to its source. I believe that great riches would be found in the country whence these Indians came. According to the route they followed they must have come from the extremity of the Eastern India, and from a very unknown region, which, according to the conformation of the coast, would be situated far in the interior of the land betwixt China and Norway. There must, in fact, be an immense distance from one sea to the other, according to the form of the coast as it has been discovered by Captain Villalobos, who took that direction in seeking for China. The same occurs when we follow the coast of Florida; it always approaches Norway up to the point where the country 'des baccalaos,' or codfish, is obtained."*

The foregoing reflections seem crude to us who are better informed with regard to the geography of the earth's surface; but when we consider that in the days of Castañeda the whole of that portion of the continent lying east of the Rio Grande was called Florida, and but little, if anything, was known of the exact relations of the northern part of our continent with the other portions of the world, they do not appear irrelevant.

In conclusion, I think it proper to observe that the "Relations" of Coronado, Castañeda, Jaramillo, and Alarcon, though somewhat vague in style, and therefore requiring a great deal of study to comprehend their meaning with certainty, are nevertheless written in a straight-forward, natural manner, and are manifestly entitled to credence whenever they describe what came under their observation. When, however, they describe the tales of others their narratives partake the character of the marvelous; but, even then, if we carry along with us the idea that they do not mean to deceive, but only to give expression to what might possibly be true—but which they do not assert to be so—their narratives must be regarded not only as truthful, but as meritorious, and eminently deserving of careful study and reflection.

* Castañeda's Relations, Ternaux Compans, pp. 183, 184.

THE SOCIAL AND RELIGIOUS CONDITION

OF

THE LOWER RACES OF MAN,

AN

ADDRESS TO THE WORKINGMEN OF LIVERPOOL.

By Sir John Lubbock, *Bart., M.P., F.R.S.*

Gentlemen: The subject on which I have been requested to address you this evening is one of much interest, but also of such vast extent, that I shall make no apology for entering at once upon it, without any introductory remarks. I will only observe that I do not propose to describe the arms or implements, houses or boats, food or dress of savages, all no doubt very interesting, but which time will not permit me to discuss; my object will rather be, if possible, to illustrate the mental condition and ideas of the lower races of men, a subject necessarily of great interest to the philosopher, but also of immense practical importance to an empire like ours, which extends to every quarter of the globe, and contains races of men in every stage of civilization.

Even those who consider that man was civilized from the beginning, and look upon savages as the degenerate descendants of much superior parents, must still admit that our ancestors were once mere savages, and may find therefore much interest in this study; but it no doubt appears far more important to those who think, as I do, that the primitive condition of man was one of barbarism, and that the history of the human race has, on the whole, been one of progress.

I do not of course suppose that every people must necessarily advance; but those who do not, will assuredly be replaced, sooner or later, by more worthy races. Nor does progress take place alike, or *pari passu*, in all nations. The Greeks, though very advanced in arts, were extremely backward in other respects. Even the most civilized races show traces, and often more than traces, of their former barbarism.

Nor do I mean that our modern savages in all respects reproduce the condition of our ancestors in early times; on the contrary, even the Australians have now codes of laws and rules which have grown up gradually, and cannot have existed originally. I feel satisfied, however, that from the study of modern savages we can gain a correct idea of man as he existed in ancient times, and of the stages through which our civilization has been evolved.

As regards their habits indeed, and the material conditions of life, savages differ greatly. The Esquimaux, in the land of ice and seals, the hunters of the American forests and prairies, the beautiful islanders of the still more beautiful islands in the Pacific, the Tartars of the Siberian steppes, the Negroes of tropical Africa, necessarily differ greatly in their diet, their clothes, their houses, &c.; but, on the other hand, as regards ideas and customs, the case is different, and we find

very remarkable similarities even in the most distinct races and the most distant regions of the globe.

I propose, therefore, on the present occasion, more especially to call your attention to the social or family relations, and the religious ideas of the lower races.

Our ideas of relationship, founded as they are on marriage, seem so natural and obvious, that we are at first inclined to regard them as having been original and common to them; this, however, as I shall attempt to show you, would be a mistake. Indeed, the position of woman is, among the lower savages, melancholy in the extreme, and precludes all those tender and sacred feelings to which so much of our best and purest happiness is due.

Again, the religion (if so it can be called) of savages differs greatly; nay, in some respects, is the very opposite of ours.

The whole mental condition of the savage, indeed, is so dissimilar from ours that it is often very difficult for us to follow what is passing in his mind, or to understand the motives by which he is actuated. Many things appear natural, and almost self-evident to him, which produce a very different effect upon us. "What," said a Negro once to Burton, "am I to starve while my sister has children whom she can sell?" Thus, though savages always have a reason, such as it is, for what they do and what they think, these reasons often seem to us irrelevant or absurd. Moreover, the difficulty of understanding what is passing in their minds is, of course, much enhanced by the differences of language.

These have produced many laughable mistakes. Thus, when Labillardière inquired of the Friendly Islanders (whose language we now perfectly understand) what was their word for 1,000,000, they seem to have thought the question absurd, and gave him a word which has no meaning; when he asked for 10,000,000, they said "*looole*," which I will leave unexplained; for 100,000,000, "*laounoua*," which means "nonsense;" while, for still higher numbers, they gave him, in joke, certain coarse expressions, which he has gravely recorded in his table of numerals.

A mistake made by Dampier led to more serious results. He had met some Australians, and apprehending an attack, he says, "I discharged my gun to save them, but avoided shooting any of them, till, finding that we were in great danger from them, and that though the gun a little frightened them at first, yet they had soon learned to despise it, tossing up their hands, and crying pooh, pooh, pooh; and coming on afresh with a great noise, I thought it high time to charge again and shoot one of them, which I did."

Thus, this wretched savage lost his life because Dampier did not remember that pooh, pooh, or puff, puff, is the name which savages, like children, apply to guns.

Again, the modes of salutation among savages are sometimes very curious, and their modes of showing their feelings quite unlike ours.

Kissing seems to us so natural an expression of affection, that we should expect to find it all over the world. Yet it was unknown to the Australians, the New Zealanders, the Paponans, the West African Negroes, and the Esquimaux.

The Polynesians and the Malays always *sit down when speaking to a superior.* In some parts of Central Africa it is considered respectful to turn the back to a superior.

Captain Cook asserts that the inhabitants of Mallicolo, an island in the Pacific Ocean, show their admiration by hissing; the Todas of the Neilgherry Hills, in India, are said to show respect by raising the open

right hand to the brow, resting the thumb on the nose; it is asserted that among the Esquimaux it is customary to pull a person's nose as a compliment; a Chinaman puts on his hat where he should take it off, and among the same curious people a coffin is regarded as a neat and appropriate present for an aged person, especially if in bad health.

Under these circumstances we cannot wonder that we have very contradictory accounts of the character and mental condition of savages. Nevertheless, by comparing together the accounts of different travelers, we can, to a great extent, eliminate these sources of error, and we are much aided in this by the remarkable similarity between very different races. So striking, indeed, is this likeness, that different races, in similar stages of development, often present more features of resemblance to one another than the same race does to itself in different stages of its history.

Some ideas, indeed, which seem to us at first inexplicable and fantastic, are yet very widely distributed. I will only allude to two.

Probably every Englishman who had not studied other races, would be astonished to meet with a nation in which, on the birth of a baby, the father and not the mother was put to bed and nursed.

Yet, though this custom seems so ludicrous to use, it prevails very widely.

Father Dobritzhoffer tells us that among the Abigrones of South America, "no sooner do you hear that a woman has borne a child, than you see the husband lying in bed, huddled up with mats and skins, lest some ruder breath of air should touch him, and for a number of days abstaining religiously from certain viands; you would swear it was he who had had the child. * * * I had read about this in old times, and laughed at it, never thinking I could believe such madness; and I used to suspect that this barbarous custom was related more in joke than in earnest, but at last I saw it with my own eyes among the Abigrones."

Other travelers mention the existence of a similar custom in Greenland, in Kamtchatka, in parts of China, in Borneo, in the north of Spain, in Corsica, and in the south of France, where it was called "*faire la convade.*"

It is of course evident that a custom so ancient and so widely distributed must have its origin in some idea which satisfies the savage mind.

Several explanations have been suggested. Professor Max Müller says, "It is clear that the poor husband was at first tyrannized over by his female relations, and afterward frightened into superstition. He then began to make a martyr of himself, till he made himself really ill, or took to his bed in self-defense."

Lafitau, to whom we are indebted for an excellent work on the manners of the American Indians, regards it as arising from a dim recollection of original sin, rejecting the explanation given by some of the savages themselves, and which I have little doubt is the correct one, that they do it because they believe that if the father is engaged in any rough work, or was careless in his diet, the infant would suffer.

This idea, namely, that a person imbibes the characteristics of an animal which he eats, is very widely distributed. The Malays at Singapore used to give a large price for the flesh of the tiger, not because they liked it, but because they believed that the man who eats tiger will become as wise and powerful as that animal. The Dyaks of Borneo have a prejudice against the flesh of the deer, which the men may not eat, though it is allowed to the women and children. The reason given is that if the men were to eat venison, they would become as timid as deer.

The Caribs will not eat the flesh of pigs or of tortoises lest they should get small eyes. The Dacotahs of North America eat the liver of the dog, that they may become as wise and brave as that animal.

The New Zealanders, after baptizing an infant, used to make it swallow pebbles, so that its heart might be hard and incapable of pity. So also after a battle, they used to cook and eat the bravest and wisest of their fallen enemies, expecting thus to secure a share of their wisdom and courage.

Another curious idea very prevalent among savages is their dread of having their portraits taken. The better the likeness the worse they think for the sitter; so much life could not be put into the copy except at the expense of the original.

Once, when a good deal annoyed by some North American Indians, Kane got rid of them instantly by threatening to draw them if they remained.

Catlin tells an amusing but melancholy anecdote in illustration of this feeling among the same people. On one occasion he was making a likeness of a chief named Mahtocheega, in profile. This, when observed, excited much commotion among the Indians. "Why was half his face left out?" they asked, "Mahtocheega was never afraid to look a white man in the face." Mahtocheega himself does not seem to have taken any offense, but Shonka, a hostile chief, took occasion to taunt him. "The Englishman," he said, "knows that you are but half a man; he has painted but one-half of your face, and knows that the rest is good for nothing." This taunt led to a fight, in which poor Mahtocheega was killed, and the whole affair was very unfortunate for Mr. Catlin, who had much difficulty in making his escape, and lived some time in fear of his life.

We cannot wonder that writing should appear to the savage even more mysterious and uncanny than drawing.

Carver allowed the Canadian Indians to open a book wherever they pleased, and then told them the number of leaves on each side. The only way they could account for this, he says, "was by concluding that the book was a spirit and told me whatever I asked."

Further south the Minnatarrees, seeing Catlin intent over a copy of the *New York Commercial Advertiser*, were much puzzled, but at length concluded that it was a cloth for sore eyes. One of them eventually bought it at a high price.

This belief in the mysterious character of writing has led to its being used in many parts of the world as a medicine.

The Central Africans are a religious people according to their lights, and have great faith in the efficacy of prayers. When any one is ill, they write a text out of the Koran on a board, wash it off, and make the patient drink it. The French traveller, Caillié, met with a man who had a great reputation for sanctity, and who made his living by writing prayers on a board, washing them off, and then selling the water, which was sprinkled over various objects, and supposed to improve and protect them. It was soon observed that the charms were no protection from fire-arms; but that did not the least weaken the faith in them, because they said, as guns were not invented in Mohammed's time, he naturally provided no specific against them.

ORNAMENTS.

Savages are passionately fond of ornaments. If in the very low races the women are often wholly undecorated, this is only because the men keep all the ornaments to themselves.

As a general rule, we may say that races inhabiting hot climates ornament themselves; those of colder countries, their clothes. In fact, all savage races who have much of their skin uncovered, delight in painting themselves in the most brilliant colors.

Although perfectly naked, the Australians of Botany Bay were, as Captain Cook quaintly puts it, "very ambitious to be fine." Through the nose they wore a bone, as thick as a man's finger, and five or six inches long. This was of course very awkward, as it prevented them from breathing through the nose; but they submitted cheerfully to the inconvenience for the sake of the appearance.

They had also necklaces made of shells neatly cut and strung together, earrings, bracelets of small cord, and strings of plaited human hair, which they wound round their waists. Some also had gorgets of large shells hung round their neck; and on all these ornaments they placed a high value.

They also painted themselves, red and white being the principal colors. The red was laid on in broad patches; the white generally in stripes, or on the face in spots, often with a circle round each eye.

Spix and Martius thus describe the ornaments of a Coroado woman, whom they saw in Brazil: "On the cheek she had a circle, and over that two strokes; under the nose several marks resembling an m; from the corners of the mouth to the middle of the cheek were two parallel lines, and below them on both sides many straight stripes; below and between her breasts there were some segments of circles, and down her arms the figure of a snake was depicted." She also wore a necklace of monkey's teeth.

Indeed, savages wear necklaces and rings, bracelets, and anklets, armlets and leglets; even, if I may say so, bodylets. Round their bodies, round their necks, round their arms and legs, their fingers, and even their toes, they wear ornaments of all kinds. Lichtenstein saw the wife of a Beetuan chief, in South Africa, wearing no less than seventy-two brass rings.

Nor are they particular as to the material—copper, brass or iron, leather or ivory, stones, shells, glass, bits of wood, seeds or teeth—nothing comes amiss. In the Louisiade Archipelago, McGillivray saw several bracelets made, each of a human lower jaw, crossed by a collar bone; and other travelers have seen brass curtain rings, brass keyhole plates, lids of sardine cases, and other such incongruous objects, worn with much gravity and pride.

Many races are very careful about their hair. The Feejee Islanders train it into elaborate wigs, which take some years to arrive at perfection, so that they cannot sleep as we do, but are compelled to use neck-rests. The islanders north of Australia, though among the lowest of savages, are in the habit of dyeing their hair red.

Not content with hanging things on their bodies wherever nature has enabled them to do so, savages often cut holes in themselves for the purpose.

The Esquimaux, from Mackenzie River westward, make two openings in their cheeks, one on each side, in which they wear stone ornaments shaped like a large shirt-stud, and which may be called cheek-studs.

Throughout a great portion of Western America, and in parts of Africa, it is the custom to wear a large piece of wood in the lower lip. A small hole is made in the lip during infancy, and it is then enlarged by degrees, the size of the lower lip being the principal criterion of beauty.

Other races, in the same manner, enlarge the lobe of the ear, until it

sometimes reaches the shoulder. Others file the teeth in various manners. Dr. Barnard Davis has a Dyack skull from Borneo, in which the six front teeth are each ornamented by having a small brass pin driven into them.

Ornamentation of the skin, again, is almost universal among the lower races of men. In some cases every individual follows his own fancy; in others, each class has its own pattern.

Thus, the Bormouese of Central Africa have twenty cuts or lines on each side of the face, one in the center of the forehead, six on each arm, six on each leg, four on each side of the chest, and nine on each side just above the hips. This makes ninety-one large cuts, and the process is said to be extremely painful, especially on account of the heat and flies.

The most familiar example, however, of this mode of ornamentation is the tattooing of the New Zealanders, which also causes much inflammation of the skin and great suffering.

Many other cases might be given in which savages ornament themselves, as they suppose, in a manner which must be very painful.

Even the shape is forcibly altered by some races of men. Thus the Chinese cripple their ladies by preventing the growth of the feet; and some of the American races even entirely alter the shape of the head, by tight bandages applied to the newly-born infant, a process which one would have expected to affect the intellect, though, as far as the existing evidence goes, it does not appear to do so.

LAWS.

Those who have not devoted much attention to the subject have generally regarded the savage as having, at least, one advantage over civilized man, that, namely, of enjoying an amount of personal freedom greater than that of individuals belonging to more civilized communities.

There cannot be a greater mistake. The savage is nowhere free. All over the world his life is regulated by a complicated set of rules and customs as forcible as laws, of quaint prohibitions, and unjust privileges—the prohibitions generally applying to the women, and the privileges to the men.

The Australians, says Mr. Laing, "instead of enjoying perfect personal freedom, as it would at first appear, are governed by a code of rules and a set of customs which form one of the most cruel tyrannies that has ever perhaps existed on the face of the earth, subjecting not only the will, but the property and life of the weak to the dominion of the strong. The whole tendency of the system is to give everything to the strong and old, to the prejudice of the weak and young, and more particularly to the detriment of the women. They have rules by which the best food, the best pieces, the best animals, &c., are prohibited to the women and young men, and reserved for the old. The women are generally appropriated to the old and powerful, some of whom possess from four to six wives; while wives are altogether denied to young men, unless they have sisters to give in exchange, and are strong and courageous enough to prevent their sisters from being taken without exchange."

In Tahiti "the men were allowed to eat the flesh of the pig and of fowls, and a variety of fish, cocoa-nuts, and plantains, and whatever was presented as an offering to the gods, which the females on pain of death were forbidden to touch, as it was supposed they would pollute them.

The fire on which the men's food was cooked was also sacred, and was forbidden to be used by the females. The baskets in which their provision was kept, and the house in which the men ate, were also sacred, and prohibited to the females under the same cruel penalty."

"To believe," says Sir George Grey, "that man in a savage state is endowed with freedom, either of thought or action, is in the highest degree erroneous."

Moreover, if savages pass unnoticed many actions which we deem highly criminal, on the other hand they strictly forbid others which we regard as altogether immaterial. Thus the Mongols of Siberia think it wrong to touch fire with a knife, to use one for taking meat out of a pot, to cut up wood near a hearth, to lean on a whip, to pour liquor on the ground, to strike a horse with the bridle, or break one bone against another.

Even in the choice of their wives, savages in many cases have rules which greatly restrict their power of selection.

In Australia (where, by the way, the same family names are common over almost the whole continent) no man may marry a woman of the same name as his own, even though she may be no relation whatever.

In Eastern Africa, Burton says that "some clans of Somal Arabs will not marry one of the same family."

Throughout India we find that the hill tribes are divided into septs or clans, and that a man may not marry a woman belonging to his own clan.

The Kalmucks of Tartary are divided into hordes, and a man may not marry a girl of his own horde. "The bride," says Bergman, "is always chosen from another stock; among the Derbets, for instance, from the Torgot stock, and among the Torgots from the Derbet stock."

The same custom prevails among the Circassians and the Samoyeds of Siberia. The Ostyaks and Yakuts also regard it as a crime to marry a woman of the same family, or even of the same name.

Among the North American Indians every tribe is divided into clans, generally from three to eight clans in each tribe, and no man is allowed to marry a woman of his own clan.

Again, far from being informal or extemporary, the salutations, ceremonies, treaties, and contracts of savages are characterized by the very opposite qualities.

Eyre mentions that, in their intercourse with one another, natives of different Australian tribes are exceedingly punctilious. Mariner gives a long account of the elaborate ceremonies practiced by the Tongans, and of their almost superstitious regard for rank. Thus, the king was by no means the man of highest rank. The Tooitonga, Veachi, and several others preceded him. Indeed the name Tooitonga means literally "Sovereign of Tonga;" the office, however, was wholly of a religious character, the Tooitonga being regarded as descended from the gods, if not as a deity himself.

The Egbas, a Negro race of West Africa, are described by Burton as extremely ceremonious, and have a great variety of salutations, applicable to every possible occasion. If an inferior meets a superior, there are several modes of showing respect. Captain Burton calculates that every one spends at least one hour a day in these troublesome ceremonies.

In the religious ceremonies of Tahiti, Williams mentions that "however large or costly the sacrifice that had been offered, and however near its close the most protracted ceremony might be, if the priest omitted or misplaced any word in the prayers with which it was accompanied, or if his attention was diverted by any means, so that the prayer was

ship had, originally, no such signification: the word daughter, for instance, meaning literally "milkmaid," and thus dating back to a time when our ancestors did not recognize the "family" as it now exists among us. Mr. Morgan has pointed out a very interesting illustration of the same fact in the language of the Sandwich Islands. The word "*waheena*" stands equally for wife, wife's sister, brother's wife, and wife's brother's wife. So again, "*kaikee*," child, also signifies brother's wife's child and wife's brother's wife's child. The same ideas of relationship are indicated by the application of the word "*kana*," *i. e.* husband.

That this does not arise from mere poverty of language is evident, because the same system discriminates between other relationships we do not distinguish from one another.

Perhaps the contrast is most clearly shown in the words for brother-in-law and sister-in-law. Thus, if a woman is speaking, the word for sister-in-law=husband's brother's wife, is *punalua*, and for sister-in-law= husband's sister, *kaikoaka;* but brother-in-law, whether sister's husband or husband's brother, is *kana*=husband. On the contrary, when a man is speaking, the word for sister-in-law=wife's sister or brother's wife, is *waheena*=wife; but brother-in-law=wife's brother, is *kaikoaka*, and for wife's sister's husband, *punalua*. Thus, a woman has husbands and sisters-in-law, but no brothers-in-law, while a man has wives and brothers-in-law, but no sisters-in-law. The same idea runs through all other relationship, cousins being regarded as brothers and sisters. So again, while the Romans distinguished between father's brother =*patmas*, and mother's brother= *avunculus;* and again, father's sister=*amita*, and mother's sister=*matertera;* the two first in Hawaian are *makua kana*.

Thus, the idea of marriage does not in fact exist in the Sandwich Island system of relationship. Uncleships, auntships, cousinships, are ignored, and we have only grandparents, parents, brothers and sisters, children, and grandchildren.

Here it is clear that the child is related to the group. It is not specially related either to its father or its mother, who stand in the same relation as mere uncles and aunts, so that every child has several fathers and several mothers.

To our English ideas, the question of the origin of marriage seems devoid of difficulty, nay, even of significance. The married state is one with which we are so familiar, it is so interwoven with all our family life, all our sense of social duty, that we are apt to regard it as universal and aboriginal. This, however, is not the case. Facts like those just referred to—and, if time permitted, many others might be given—show that the condition of the lowest races of men is that not of individual marriage as it exists among us, but of communal marriage, if I may call it so. Even, however, under the system of communal marriage, a man who had captured a beautiful girl in some marauding expedition would wish to keep her to himself. She did not belong to the tribe; they had no right to her; he might have killed her if he had chosen; and if he preferred to keep her alive, it was no affair of theirs; she was as much his individual property as his spear or his bow. Hence a form of individual marriage would rise up by the side of the communal marriage. This theory explains the extraordinary subjection of the woman in marriage; it explains the very widely distributed custom of "exogamy," or that custom which forbids marriage within the tribe; the necessity of expiation for marriage, as an infringement of tribal rights, since, according to old ideas, a man had no right to appropriate to himself that which belonged to the whole tribe; and, lastly, the remarkable prevalence of the form of capture in marriage.

Among the rudest races capture is far more than a form, and it is customary for men to steal women by force from other tribes.

Hearne, who knew the North American Indians thoroughly well, and whose statements have been confirmed by subsequent travelers, as for instance by Franklin and Richardson, assures us that among the Northern tribes, it has ever been the custom for the men to wrestle for any woman to whom they are attached; and of course the strongest always carries off the prize. "A weak man," he adds, "is seldom permitted to keep a wife, that a stronger man thinks worth his notice," which, he says, "keeps up a great spirit of emulation among the young men." It must be observed that this is not regarded as any arbitrary exercise of power, but it is a recognized right that a strong man may carry off the wife of a weaker one if he can; and it would appear that even the women acquiesce in this custom without a murmur.

I will now give a few instances, in order to show how widely this custom of marriage by capture prevails among the lower races of men, and that traces of it linger even among those higher in the scale of civilization.

In Australia, the ardent lover steals on the dark object of his affections, knocks her down with his club, and drags her off in triumph. This violent affection is not resented by the relations of the woman, if they are not able to rescue her at the moment. On the contrary, she is recognized as the legal wife of her captor.

In Bali, one of the islands between Java and New Guinea, it is stated to be the practice that girls are stolen away by their lovers, who carry them off by force to the woods; when brought back from thence the poor female becomes the slave of her rough lover, by a certain compensation being paid to her relatives.

Speaking of the Khonds, a tribe in India, Major General Campbell mentions that, on one occasion, hearing loud cries, he went to see what was the matter, and found a man carrying off a girl, while twenty or thirty friends protected him from the attacks of a number of women, who were attempting to rescue the bride. The struggle continued until the bridegroom reached his own house, and General Campbell was assured that, among the Khonds, marriages were always solemnized in this manner.

Among the Kalmucks of Central Asia the marriage ceremony is even more romantic. The girl is put on a horse and rides off at full speed. When she has got enough start the lover starts in pursuit; if he catches her, she becomes his wife; but if he cannot overtake her, the match is broken off; and we are assured, which I can well believe, that no Kalmuck girl was ever caught against her will.

Again, among the Ahitas of the Philippine Islands, when a man wishes to marry a girl, her parents send her before sunrise into the woods. She has an hour's start, after which the lover goes to seek her. If he finds her and brings her back before sunset, the marriage is acknowledged; if not, he must abandon all claim to her.

"The aborigines of the Amazon Valley," says Wallace, "have no particular ceremony at their marriages, except that of always carrying away the girl by force, or making a show of doing so, even when she and her parents are quite willing."

M. Bardel mentions that among the Indians round Conception, in Chili, on the other side of the Andes, after a man has agreed on the price of a girl with her parents, the recognised mode of proceeding is that he surprises her, or is supposed to do so, and carries her off to the woods for a few days, after which the happy couple return home.

As regards Europe, we find just the same thing; the Romans had a similar custom, and traces of it occur in Greek history.

So deeply rooted is the feeling of a connection between force and marriage, that we find the former used as a form long after all necessity for it as a reality had ceased to exist; and it is very interesting to trace, as Mr. McLennan has done, the gradual stages through which a stern reality softens down into a mere symbol.

For, as communities became larger and more civilized, the *actual capture became inconvenient*, and, indeed, impossible. Gradually, therefore, it sunk more and more into a mere form.

In North Friesland the bride makes a show of resistance, and is lifted by mock force into the wagon which is to take her home.

Hence, no doubt, the custom of lifting the bride over the doorstep, which occurs or did occur among the Romans, the redskins of Canada, the Chinese, and the natives of Abyssinia. Hence, also, perhaps our custom of the honeymoon; and hence, also, may be, as Mr. McLennan has suggested, the slipper is thrown in mock anger after the departing bride and bridegroom. The latter suggestion is indeed very doubtful; still it is remarkable how persistent are all customs and ceremonies connected with marriage. Thus our "bridecake," which so invariably accompanies a wedding, and which must always be cut by the bride, may be traced back to the old Roman form of marriage by "*confarreatio*," or eating together. So also among the Iroquois, the bride and bridegroom used to partake together of a cake of sagamite, which the bride always offered to her husband. Again, among several of the Indian Hill tribes, the bride prepares some drink, sits on her lover's knee, drinks half herself, and gives him the rest.

It requires strong evidence, which, however, exists in abundance, to satisfy us that marriage was, in its origin, independent of all sacred and social considerations; that it had nothing to do with mutual affection or consent; indeed, that all appearance of consent was forbidden; so that it was symbolised not by any demonstration of warm affection on the one side, and tender devotion on the other, but by brutal violence and unwilling submission.

Yet, as already mentioned, the evidence is overwhelming. Marriage by capture, either as a reality or as a form, has been shown to exist in Australia, and among the Malays, in Hindostan, Central Asia, Siberia, and Kamtchatka, among the Esquimaux, the northern redskins of America, the aborigines of the Amazon Valley, in Chili and in Tierra del Fuego, in the Pacific Islands, in the Philippines; among the Arabs, Negroes, and Circassians; and, until lately, in various parts of Northern Europe.

I will now proceed to the consideration of the statement that the second stage in the development of the idea of family consists in the recognition of relationship to the mother, that to the father being still overlooked.

In almost all tropical countries polygamy is very frequent; the chiefs especially take to themselves a large number of wives. In Western Africa, for instance, the king of Ashantee made it a point of honor to have always 3,333 wives. Among hunting races, though polygamy is less prevalent, men who are powerful, either physically or socially, frequently appropriate to themselves the wives of those who are weaker. Either of these conditions—either the multiplicity of wives, or frequent changes, would weaken very much the tie between father and child. Hence, probably, the curious fact, that in many parts of the world a man's property does not descend to his own children, but to those of his

sister; relationship, and, consequently, inheritance, being held to descend in the female line, and not in the male, as among ourselves.

This is the case among the Negroes of Guinea, among the Berbers in North Africa, and the Arabs in the East. It occurs among several of the Hindostan tribes, among the Battas of Sumatra, the red Indians of North America, the black islanders of the Pacific, and elsewhere.

Obviously, however, as civilization progressed, and the moral feelings became stronger, a feeling of opposition to these arrangements would arise. As family life became more developed, the affection between father and child would become stronger; and as property became more important, men would wish their goods to descend to their own children, who would themselves obviously desire to inherit their father's property.

And as man, like a pendulum, always passes from one extreme to another, so, having long considered that children were related to their mother, but not to their father, when they recognized the relation on the paternal side, they went into the other extreme, and neglected that to the mother.

How completely the idea of relationship through the father, when once recognized, superseded that through the mother, we may see in the very curious trial of Orestes—the son of Agamemnon and Clytemnestra—as recorded by an ancient Greek poet.

Clytemnestra murdered Agamemnon, whose death was avenged by Orestes. For this act he was fabled to have been prosecuted before the Greek gods by the Furies, whose duty it was to punish those, and those only, who had slain their relatives.

In his defense Orestes asked them, why they did not punish his mother, Clytemnestra, for the murder of her husband, Agamemnon, and when they answer that marriage does not constitute blood-relationship, he pleads that, by the same rule, they cannot touch him, because, he says, a child is a relation to his father, but not to its mother.

This view, which seems to us so unnatural, was nevertheless supported by Apollo and Minerva, and being adopted by a majority of the judges, led to the acquittal of Orestes.

Hence we see that at first the feeling of clanship prevailed rather than that of family, and that children were regarded as related to the tribe rather than to their parents; that, secondly, they were considered to be related to the mother, but not to the father; thirdly, to the father, but not to the mother; lastly, and lastly only, as among ourselves, to both father and mother.

We see, therefore, that the lowest savages are entirely deficient in the idea of marriage and of family, and that the position of women is wretched in the extreme. The ideas of relationship, founded on marriage, have only gradually been acquired, and thus civilization has raised the position of woman, and making her a helpmeet instead of a slave, has purified and softened all the conditions of social life. The higher position of woman is one of the points in which we see most clearly the enormous advantage of civilization over barbarism.

RELIGION.

The religious condition of the lower races of mankind is one of the most difficult, although, at the same time, most interesting portions of my subject.

It is most difficult, partly because it is far from easy to communicate with men of a different race on such an abstruse subject; partly because many are reluctant to discuss it; but mainly because, even among those nominally professing the same religion, there are always in reality great

differences; individuals—as I shall endeavor to show you is also the case with nations—acquiring continually grander, and therefore more correct ideas, as they rise in the scale of civilization.

Still, as new religious ideas arise, they do not destroy, but are only superinduced upon the old ones; thus the religion of the ancestors become the nursery tales of their descendants, and the old Teutonic deities of our forefathers are the giants and demons of our children.

It has hitherto been usual to classify religions either according to the name of the founder or the objects worshipped. Thus one division of the lower religions has been into Fetichism, defined as the worship of material substances; Sabæism, that of the heavenly bodies, the sun, moon, and stars; and Heroism, or the deification of men after death. This and other similar systems are simple, and have certainly some advantages, especially as regards the lower races of men and the lower forms of religion. They are not, however, really natural systems; there is no real difference between the worship of the sun and that of a rock or lake. No doubt to us the sun seems a grander deity, but of the main facts on which that opinion rests the savage is entirely ignorant.

Moreover, Heroism is found among races as low in the scale of civilization as either Fetichism (in the above definition, which, however, I do not adopt) or Sabæism, and indeed the three forms of religion indicated above may coexist in one people, and even in the same individual. The true classification of religions should, as it seems to me, rest, not on the mere object worshipped, but on the nature and character ascribed to the deity.

It is a much disputed question, into which I will not now enter, whether the lowest races have any religion or not.

However this may be, it is at least clear that the religion of the lower savages is very unlike that of most advanced races. Indeed, in many respects it is the very opposite. Their deities are evil, not good; they may be forced into compliance with the wishes of man; they require bloody, and rejoice even in human, sacrifices; they are mortal, not immortal; part of nature, not the creators of the world; they are to be approached by dances rather than by prayers; and often approve of vice rather than of what we esteem as virtue.

The ideas of religion among the lower races of man are intimately associated with, if indeed they have not originated from, the condition of man during sleep, and especially from dreams.

Sleep and death have always been regarded as nearly related to one another. Thus, in classical mythology, Somnus, the god of sleep, and Mors, the god of death, were both fabled to have been the children of Nox, the goddess of night.

So, also, the savage would naturally look on death as a kind of sleep, and would expect and hope—hoping on even against hope—to see his friend awake from the one as he had often done from the other.

Hence, probably, one reason for the great importance ascribed to the treatment of the body after death.

But what happens to the spirit during sleep? The body lies lifeless, and the savage not unnaturally concludes that the spirit has left it. In this he is confirmed by the phenomena of dreams, which consequently to the savage have a reality and an importance which we can scarcely appreciate. During sleep the spirit appears to desert the body, and, as in our dreams, we seem to visit other countries and distant regions, while the body remains as it were lifeless; the two phenomena were naturally placed side by side, and regarded as the complements one of the other.

Hence, the savage considers the events in his dreams as real as those which happen when he is awake, and hence he naturally feels that he has a spirit which can quit the body—if not when it likes, at least under certain circumstances.

Thus, Burton states, that, according to the Jorubans, a Western African tribe, "dreams are not an irregular action and partial activity of the brain, but so many revelations from the spirits of the departed."

So strong, again, was the North American faith in dreams, that on one occasion, when an Indian had dreamed that he was taken captive and tortured, he induced his friends to make a mock attack upon him, and actually submitted to very considerable suffering, in the hope that he would thus fulfill his dream.

The Greenlanders also believe in the reality of dreams, and think that at night their spirit actually goes hunting, visiting, courting, and so on. It is of course obvious that the body takes no part in these nocturnal adventures, and hence it is natural to conclude that they have a spirit which can quit the body.

Lastly, when they dream of their departed friends or relatives, savages firmly believe that they are visited by the spirits of the dead, and hence believe, not indeed in the immortality of the soul, but in the existence of a spirit which survives, or may survive, the body.

Again, savages are seldom ill; their sufferings generally arise from wounds; their deaths are generally violent. As an external injury received, say, in war, causes pain, so when they suffer internally, they attribute it to some enemy within them. Hence, when an Australian, perhaps after too heavy a meal, has his slumbers disturbed, he is at no loss for an explanation, and supposes that he has been attacked by some being whom his companions could not see.

This is well illustrated in the following passage from Captain Wilkes's voyage: "Sometimes," he says, "when the Australian is asleep, Koin, as they call this spirit, seizes upon one of them and carries him off. The person seized endeavors in vain to cry out, being almost strangled. At daylight, however, Koin departs, and the man finds himself again safe by his own fireside." Here it is evident that Koin is a personification of the nightmare.

In other cases the belief that man possesses a spirit seems to have been suggested by the shadow. Thus, among the Feejeeans: "Some," says Mr. Williams, "speak of man as having two spirits. His shadow is called the 'dark spirit,' which they say goes to Hades. The other is his likeness reflected in water or a looking-glass, and is supposed to stay near the place in which a man dies. Probably this doctrine of shadows has to do with the notion of inanimate objects having spirits. I once placed a good-looking native suddenly before a mirror. He stood delighted. 'Now,' said he softly, 'I can see into the world of spirits.'"

But though spirits are naturally to be dreaded, on various accounts, it by no means follows that they should be conceived as necessarily wiser or more powerful than man. Of this our spirit-rappers and table-turners afford us a familiar illustration. So also, the natives of the Nicobar Islands put up scarecrows round their villages to frighten away hostile spirits. The natives of Kamtchatka insult their deities if their wishes are unfulfilled. They even feel a contempt for them. "If Kutka," they say, "had not been stupid, would he have made inaccessible mountains and too rapid rivers?"

The Lapps made images of their gods, putting each in a separate box, on which was written the name of the deity, so that each might know its own box.

The Kyoungtha, of Chittagong, are Buddhists. Their village temples contain a small stand of bells, and an image of Boodh, which the villagers generally worship morning and evening; "first," as Captain Lewin states, "ringing the bells to let him know they are there." The Sinto temples of the Sun Goddess in Japan also contain a bell, intended, as Bishop Smith tells us, "to arouse the goddess, and to awaken her attention to the prayers of her worshippers."

Casalis states that when a Kaffir is on a marauding expedition, he gives utterance to those cries and hisses in which cattle-drivers indulge when they drive a herd before them, thinking in this manner to persuade the poor divinities of the country they are attacking, that he is bringing cattle to their worshippers, instead of coming to take it from them.

Many other illustrations might be given, but these are sufficient to show how low and degraded is the savage conception of the Divine nature. Gradually, however, as the human mind expands, it becomes capable of higher and higher realizations.

I will now describe very shortly the religions of some savage races, beginning with the lowest, which may be called Animism.

The religion of the Australian, if it can be so called, consists of a belief in the existence of ghosts, or spirits, or at any rate of evil beings who are not mere men. This belief cannot be said to influence them by day, but it renders them very unwilling to quit their camp-fire by night, or to sleep near a grave. They have no idea of creation, nor do they use prayers; they have no religious forms, ceremonies, or worship. They do not believe in a Supreme Deity, or in the immortality of the soul, nor is morality in any way connected with their religion.

An interesting account of the religious condition of the northern natives has been given by a Mrs. Thomson, a Scotchwoman, who was wrecked on that coast, and lived alone with the natives for nearly five years, when she was rescued by a English ship. The Australians all over the continent have an idea that when the blacks die they turn into whites. Mrs. Thomson herself was taken for the ghost of a woman named Giom, and when she was teased by the children, the men would often say, "Leave her alone, poor thing; she is nothing, only a ghost."

This, however, did not prevent a man named Baroto making her his wife, which shows how little is really implied in the statement that the Australians believe in the existence of spirits. In reality they do no more than believe in the existence of men slightly different from and somewhat more powerful than themselves.

FETICHISM.

The Fetichism of the Negro is a step in advance, because the influence of religion is much raised in importance. Nevertheless, from one point of view, Fetichism may be regarded as an anti-religion; for the Negro believes that by means of the Fetich he can coerce and control the deity.

Indeed, Fetichism is mere witchcraft. We know that all over the world would-be magicians think that if they can obtain a part of an enemy, or even a bit of his clothing, they thus obtain a control over him.

Nay, even the knowledge of the name is supposed to confer a certain power. Hence the importance which savages attach to names. Thus, for instance, the true name of the beautiful Pocahontas, a celebrated Virginian chieftainess, was Matokes; but this name was carefully concealed from the English, lest it should give them a power over her. For

the same reason the Romans carefully concealed the name of the patron saint of their city.

In other cases it was thought sufficient to make an image to represent the original. Thus, even in the 11th century, and in Europe, some unfortunate Jews were accused of murdering a certain Bishop Eberhard, by making a wax figure to represent him, and then burning it, whereby the bishop died; this indeed was a common form of witchcraft.

Now, Fetichism seems a mere extension of this belief. The Negro supposes that the possession of a Fetich representing a deity makes that deity his slave.

A Fetich, therefore, differs essentially from an idol. The one is intended to raise man to the contemplation of the deity; the other to bring the deity within the control of man. Aladdin's lamp is a familiar instance of a Fetich; and indeed, if witchcraft be not confused with religion, Fetichism can hardly be called a religion.

The low religious conceptions of the Negroes are well illustrated in the general belief that the Fetich sees with its eyes as we do; and so literally is it the actual image which is supposed to see, that, when the Negro is about to do anything of which he is ashamed, he hides his Fetich in his waistcloth, so that it may not be able to see what is going on. Fetichism, strictly speaking, has no temples, idols, priests, sacrifices, or prayer. It involves no belief in creation, or in a future life, and, *a fortiori*, none in a state of future rewards and punishments: it is entirely independent of morality.

TOTEMISM.

The next stage in religious progress is that which may be called Totemism. The savage does not abandon his belief in Fetichism, from which indeed no race of man has yet entirely freed itself, but he superinduces on it a belief in beings of a higher and more mysterious nature. In this stage everything is deified—stones, rivers, lakes, mountains, the heavenly bodies, even animals and plants.

Various theories have been suggested to account for the origin of the deification of such objects. I believe that it arose principally in this way: A chief being named after some tree or animal, say the Black Bear, or the Eagle, his family would naturally take the same name. They would then come to look on the animal after which they were named, first with interest, then with respect, and at length with a sort of awe.

In Australia, we seem to find the Totem, or, as it is there called, the "Kobong," in the very process of deification. Sir George Grey tells us that each family takes some animal or plant as its sign or "Kobong." No native will intentionally kill or eat his "Kobong," which shows that there is a mysterious feeling connected with it; but we are not told that in Australia the Kobong is regarded as a deity.

In America, on the other hand, the redskins worship their Totem, from which they believe themselves to be actually descended.

If we remember how low is the savage conception of a deity, we shall see that the larger and more powerful animals do, in fact, to a great extent, fulfill his idea.

This is especially the case with nocturnal animals, such as the lion and tiger. As the savage crouching by the side of his camp-fire at night listens to the cries and howls of the animals prowling round, or watches them stealing like shadows among the trees, what wonder if he weaves mysterious stories about them, and eventually fancies them something more mysterious than mere mortal beings.

The worship of the serpent is very prevalent. Its bite, so trifling in appearance, and yet so deadly, producing fatal effects rapidly, and apparently by no adequate means, suggests to the savage almost irresistibly the notion of something divine, according to his notions of divinity.

There were also some lower, but powerful considerations, which tended greatly to the development of serpent-worship. The animal is long-lived, and easily kept in confinement; hence the same individual might be preserved for a long time, and easily exhibited at intervals to the multitude. In Guinea, where the sea and the serpent were the principal deities, the priests encouraged the worship of the latter expressly, as we are told, because offerings presented to the sea were washed away by the waves, which was not the case with those offered to the serpent.

It is somewhat more difficult to understand the deification of inanimate objects. In fact, however, savages scarcely believe in the existence of inanimate objects. Chapman mentions that the Bushmen in South Africa thought his big wagon was the mother of his small one. Hearne tells us, that the North American Indians never hang up two nets together, for fear they should be jealous of one another, and that they prefer a hook which has caught a big fish to fifty which have not been tried.

The South Sea Islanders not only believed that their animals had souls, but also that this was the case with inanimate objects. Hence, the savage broke the weapons and buried with the dead, so that their souls might accompany that of their master to the land of spirits. Hence, also, on one occasion the king of the Koussa Kaffirs having broken a piece of iron from a stranded anchor, died soon after, upon which the Kaffirs immediately concluded that the anchor was alive and had killed their king.

Some such accident probably gave rise to the ancient Mohawk notion, that some great misfortune would befall any one who spoke while crossing Saratoga Lake. A strong-minded English woman on one occasion purposely did so; and, after landing, rallied her boatman on his superstition; but I think he had the best of it after all, for he at once replied, that the Great Spirit was merciful, and knew that a white woman could not hold her tongue.

We find, indeed, the worship of lakes and rivers, or traces of it, all over the world. Even our own island is full of sacred wells and springs, and Scotland and Ireland especially abound with legends about water-spirits. I have myself seen a well in Rosshire hung round with the offerings of the peasantry, consisting principally of rags and half-pence.

The worship of upright stones is also very widely distributed. This form of worship has been explained by M. Dulaure as arising from the respect paid to boundary stones. I do not doubt that, in the case of some particular stones, it may have so arisen. The heathen deity, Hermes, or Termes, was evidently of this character, and hence we may explain the peculiar and apparently antagonistic peculiarities attached to him.

"Mercury or Hermes," says Lemprière, "was the messenger of the gods; he was the patron of travelers and shepherds; he conducted the souls of the dead into the infernal regions, and not only presided over orators, merchants, and declaimers, but was also the god of thieves, pickpockets, and all dishonest persons. He invented letters and the lyre, and was the originator of the arts and sciences."

It is difficult at first to see the connection between these various offices, characterized as they are by such opposite peculiarities. Yet they all follow from the custom of making boundaries by upright stones.

Hence the name of Hermes or Termés, a boundary or terminus, while the name of the corresponding Roman deity, Mercury, is connected with the word "march," or boundary, whence our title of marquis, meaning originally a person to whom was intrusted the duty of guarding the "march," or neutral territory, which in the troublous times of old it was customary to leave between the possessions of different nations.

These marches, not being cultivated, served as grazing grounds; to them came merchants to exchange on neutral ground the products of their respective countries; here also, for the same reason, treaties were negotiated; here also international games and sports were held. Upright stones were used to indicate places of burial; and lastly, on them were inscribed laws and decrees, records of remarkable events, and the praises of the deceased.

Hence Mercury, represented by a plain upright stone, was the deity of travelers, because he was a landmark; of shepherds, as presiding over pastures; he conducted the souls of the dead into the infernal regions, because even in the very early days upright stones were used as tombstones; he was the god of merchants, because commerce was carried on mainly at the frontiers; and of thieves out of sarcasm. He was the messenger of the gods, because ambassadors met at the frontiers; and of eloquence, for the same reason. He invented the lyre and presided over games, because contests in music, &c., were held on neutral ground; and he was said to have invented letters, because inscriptions were engraved on upright pillars.

Stone-worship in its lower phases has, however, I think, a different origin, and is merely a form of that indiscriminate worship which characterizes the human mind in one phase of development.

Fire, again, is worshipped all over the world. In ancient times it was far from being so easy to light a fire as it is now that we have lucifer matches and various other appliances for the purpose. In some parts of Tasmania and Australia the natives, if their fires went out, preferred to go long distances to get a fresh spark from another tribe rather than attempt to light one for themselves.

In somewhat more advanced communities, as, for instance, in some of the North American tribes, and in the familiar instance of Rome, certain individuals were told off to keep a fire continually burning. Thus would naturally arise the idea that this fire was something sacred and holy. The name of the classical goddess of fire, Vesta, or Hestia, means literally a hearth.

The worship of fire naturally reminds us of that of the heavenly bodies, and especially of the sun and moon. When once the idea of religion had arisen, no one can wonder that they should be regarded as deities. To us indeed this worship seems to contain much that is grand; and while many writers have refused to believe it possible that man could ever really have worshipped animals and plants, almost all have regarded that of the sun and moon as natural and appropriate.

Yet the sun and moon do not appear to have suggested the idea of divinity to the savage mind by any other process than that already alluded to in the case of animals. The lowest races have never raised their minds to the contemplation of the sun or moon as deities. This worship commences only in the stage above Fetichism, that is to say, as a form of Totemism; but it reaches its greatest importance at a subsequent stage of religious development. Before quitting Totemism, it may be well to observe that even objects most inappropriate, according to our ideas, have been deified by various races.

Thus, in Central India, the Todas are said to worship a buffalo bull,

pouring out libations of milk, and offering prayers to it. The Kotas worship two silver plates, which they regard as husband and wife. They have no other deity. The Kinumbas worship stones, trees, and ant-hills. The Toreas, another neighboring hill tribe, worship especially a gold nose-ring, which probably once belonged to one of their women.

Many other inanimate objects have also been worshipped. Debrosses mentions an instance of a king of hearts being made into a deity.

The South Sea Islanders, who represent a distinctly higher phase of civilization than the hill tribes of Hindostan, or the red Indians of North America, present us also with a higher form of religion. Their deities are conceived as more powerful. In many islands there are traditions of a powerful being who raised the land from below the waters, and in Tonga, until lately, it is said that the very hook was shown with which this was effected; still the deities cannot be regarded as creators, because both earth and water existed before then. Neither was the religion of the South Sea Islanders connected with morality. Their deities were not supposed to reward the good or to punish the evil. In the Tonga and other islands the common people were not supposed to have souls at all. In Tahiti the natives believed in a future life, and even in the existence of separation between the spirits, some going to a much happier place than others. This, however, was not considered to depend on their conduct during life, but on their rank—the chiefs going to the happier, the remainder of the people to the less desirable locality.

The Feejeeans believe that, as they die, such will be their condition after death. Moreover, the road to *mbulu*, or heaven, is long and difficult; many souls perish by the way, and no diseased or infirm person could possibly succeed in overcoming all the dangers of the road. Hence, as soon as a man feels the approach of old age, he notifies to his children that it is time for him to die. A family consultation is then held, a day appointed, and the grave dug. Mr. Hunt gives a striking description of such a ceremony once witnessed by him. A young man came to him and invited him to attend his mother's funeral, which was just going to take place. Mr. Hunt accepted the invitation and joined the procession, but was surprised to see no corpse. He asked where the mother was, when the young man pointed out his mother, who, in Mr. Hunt's words, was walking along "as gay and lively as any of those present." When they arrived at the grave, she took an affectionate farewell of her children and friends, and then cheerfully submitted to be strangled.

So general, indeed, was this custom in the Feejee Islands, that in many villages there were literally no old people, all having been put to death; and if we are shocked at the error which led to such dreadful results, we may at least see something to admire in the firm faith with which they acted up to their religious belief.

It will be observed that, up to this stage, religion is entirely deficient in certain characteristics with which it is generally regarded as intimately associated. The deities are mortal; they are not creators; no importance is attached to true prayers; virtue is not rewarded, nor vice punished; there are no temples or priests; and, lastly, there are no idols.

Up to this stage, indeed, we find the same ideas and beliefs scattered throughout the whole world, among races in the same low stage of mental development.

From this point, however, differences of circumstance, differences of government, differences of character, materially influence the forms of religious belief. Natives of cold climates regard the sun as beneficent,

those of the tropics consider him as evil; hunting races worship the moon, agriculturists the sun; again, in free communities thought is free, and, consequently, progressive; despots, on the contrary, by a natural instinct, endeavor to strengthen themselves by the support of spiritual terrors, and hence favor a religion of sacrifices and of priests rather than one of prayer and meditation.

Lastly, the character of the race impresses itself on the religion. Poetry especially exercises an immense influence, as, for instance, has been well shown by Max Müller and Cox to have been the case with the Greeks, the names of the Greek gods reappearing in the earlier Vedic poetry as mere words denoting natural objects. Thus, Dyaus, in ancient Sanscrit, means simply the sky; and the expression, the "sky thunders," meant originally no more than it does with us. The Greeks and Romans, however, personified Dyaus, or Zeus; thus, they came to regard him as a deity, the god of thunder, the lord of heaven, and thus built up a whole mythology out of what were at first mere poetical expressions. Time, however, does not permit me to enter on this interesting part of the subject. I trust, however, that what I have said shows that the opinions of savages, as regards religion, differ essentially from those prevalent among us. Their deities are scarcely more powerful than themselves; they are evil, not good; they are to be propitiated by sacrifices, not by prayer; they are not creators; they are neither omniscient nor all-powerful; they neither reward the good nor punish the evil; far from conferring immortality on man, they are not even, in all cases, immortal themselves.

Where the material elements of civilization developed themselves without any corresponding increase of knowledge, as, for instance, in Mexico and Peru, a more correct idea of Divine power, without any corresponding enlightenment as to the Divine nature, led to a religion of terror, which finally became a terrible scourge of humanity.

Gradually, however, an increased acquaintance with the laws of nature enlarged the mind of man. He first supposed that the deity fashioned the earth, raising it out of the water, and preparing it as a dwelling-place for man; and subsequently realized the idea that land and water were alike created by Divine power. After regarding spirits as altogether evil, he rose to a belief in good as well as in evil deities, and gradually subordinating the latter to the former, worshipped the good spirits alone as gods, the evil sinking to the level of demons.

From believing only in ghosts, he came gradually to the recognition of the soul; at length uniting this belief with that in a beneficent and just being, he connected morality with religion, a step the importance of which it is scarcely possible to over-estimate.

Thus we see that as men rise in civilization their religion rises with them; that far from being antagonistic to religion, without science, true religion is impossible.

The Australians dimly imagine a being, spiteful, malevolent, but weak, and dangerous only in the dark.

The Negro's deity is more powerful, but not less hateful. Invisible, indeed, but subject to pain, mortal like himself, and liable to be made the slave of man by enchantment.

The deities of the South Sea Islanders are some good, some evil; but on the whole, more is to be feared from the latter than to be hoped from the former. They fashioned the land, but are not truly creators, for earth and water existed before them. They do not punish the evil, nor reward the good. They watch over the affairs of men; but if, on the one hand, witchcraft has no power over them, neither, on the other, can

prayer influence them; they require to share the crops or the booty of their worshipers.

Thus, then, every increase in science—that is, in positive and ascertained knowledge—brings with it an elevation of religion.

Nor is this progress confined to the lower races. Even within the last century, science has purified the religion of Western Europe by rooting out the dark belief in witchcraft, which led to thousands of executions, and hung like a black pall over the Christianity of the Middle Ages.

Yet, in spite of these immense services which science has confessedly rendered to the cause of religion, there are still many who look on it as hostile to religious truth, forgetting that science is but exact knowledge, and that he who regards it as incompatible with his religion, practically admits that his religion is untenable.

Others, again, maintain that although science or religion cannot indeed be at variance, yet that the teaching of scientific men, or rather of some scientific men, is in open hostility with religion.

What justification is there, however, for this idea? No scientific man, so far as I know, has ever been supposed to have taught anything which he did not himself believe. That surely was their right—nay, their duty; their duty alike to themselves, to you, for their devotion to truth is their best claim to your confidence—nay, to religion also, for nothing could be more fatal to religion than that it should be supposed to require the suppression of truth.

No, the true spirit of faith looks on the progress of science, not with fear but with hope, knowing that science can influence our religious conceptions for good only.

Whether, then, as some suppose, science is destined profoundly to modify our present religious views, or not—into which question I do not now wish to enter—no one need on that account regard it with apprehension or with distrust.

Far from it, we must be prepared to accept any conclusions to which the evidence may lead; not in the spirit of resignation or of despair, but in the sure and certain hope that every discovery of science, even if it may conflict with our present opinions, and with convictions we hold dear, will open out to us more and more the majestic grandeur of the universe in which we live, and thus enable us to form nobler and therefore truer conceptions of religious truth.

The time, then, has surely now come, when scientific men need no longer stand on the defensive, but may call on the state, which is now making a great effort to establish a national system of education, and has ever shown itself ready to assist in the prosecution of scientific research—may call on the clergy, who exercise so great an influence—no longer to ignore in our elementary and other schools the great discoveries of the last thousand years, but to assist us in making them more generally known to the people of this country; confident that a better acquaintance with the laws which regulate the beautiful world in which we live would not only diminish the evils from which we suffer, and add greatly to the general happiness, but also tend to develop our moral nature—to elevate and purify the whole character of man.

PRINCIPLES AND METHODS OF PALAEONTOLOGY.

By Thomas Henry Huxley.

[The following article was published, in 1865, in "A Catalogue of the Collection of Fossils in the Museum of Practical Geology," &c. Although evidently written, at least in part, long before its publication, it still remains one of the clearest and most complete summaries of the subject yet published, and as the want of such a summary has been frequently expressed, it is here reproduced. On account, however, of its length, certain passages of simple local interest have been omitted.—H.]

I.—Preliminary considerations.

The formation of the collection of fossils in the Museum of Practical Geology has been a necessary result of the operations of the geological survey of Great Britain, whose officers have been engaged for many years past in determining the structure of the British islands; that is, in ascertaining what is the nature and the order of superposition of the various irregular masses or regular "strata,"* piled one upon another, which compose these like all other parts of the earth's crust.

If rocks and stones were soft and easily cut, nothing would be easier than the solution of these questions. It would be merely necessary to make a sufficiently deep vertical cutting of the country in any required direction, and the true order of the beds would be at once visible on the walls of the section. But it is needless to say that in practice cutting into rocks is a very difficult and a very expensive operation, and that the making of such artificial sections as these, for geological purposes, is wholly out of the question. The geological surveyor is, therefore, obliged to trust very largely to the accidental occurrence of natural sections, such as are afforded by the sea cliffs or the scarped hills which may occur in his line of work, and to such artificial aids as are incidentally yielded by the sinking of shafts or the cutting of railroads.

It becomes, consequently, of essential importance to him to possess a means of identifying the beds which he finds in one section with those in another. Similarity or dissimilarity of mineralogical composition will not always help him, as this quality not only varies in the same stratum, but is similar in widely different strata; so that beds of limestone in one place may correspond as regards age and position with sandy or clayey strata elsewhere. On the other hand, the continuity of a stratum between any two points examined would be clear and decisive as to its identity at the two points, but this evidence, for the reasons just stated, is but rarely attainable; and where, as so frequently happens, the strata have been disturbed from their original position, widely separated, or partially destroyed between the two points, it becomes hopeless to seek for any such proof. Were there no other test of the nature of a stratum at any given point than its mineral character, and its continuity with some other stratum whose place in the series was known, we might

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* Stratum.—A single layer of the earth's crust, whatever its composition, is technically termed a stratum. For simplicity's sake, the often highly irregular masses of igneous rock which enter largely into the composition of the earth's crust, and which might not technically be termed "strata," may be left out of consideration.

have a series of local topographies, but no science of geology; nor could those great laws ever have been established by which the geologist, acquainted with the surface rock of a country, is enabled to predict with much confidence what may, and what cannot, be found beneath it.

These laws are in truth entirely based on the study of the "fossils" contained in the rocks; it is upon this science of fossils, or "palaeontology,"* that another and most important method of determining the nature and order of the strata rests. Universal experience has shown that every series of strata contains assemblages of fossils which are peculiar to and characteristic of it; which are usually found in it, and never found out of it; and observation has further demonstrated that the strata thus characterized are arranged in an order of superposition which is everywhere constant. It follows, therefore, that the fossils contained in a stratum of rock are capable of revealing to us, at once, the position of that stratum in the whole series, and of informing us what lies above and what below it.

A common example will illustrate the practical value of the information thus obtained.

It is shown by experience that in these islands extensive beds of good workable coal are never found below that particular series of strata termed, collectively, the "carboniferous formation." Nevertheless, fossilized vegetable matters occur in other strata, and have not unfrequently misled owners of estates into undertaking ruinously expensive and wholly fruitless mining operations, which would never have been commenced had they availed themselves of the information afforded by the fossils of the surface rocks. For it is clear that a preliminary examination of these fossils will show at once whether they belong to strata below the carboniferous rocks or above them. If the former be the case, then the sinking a shaft is absurd, as every blow of the pickaxe must take the miner, in reality, further away from the object of his search; if the latter, on the other hand, success is at any rate possible, though the expediency of making the attempt will depend upon many contingencies.

Now it is clear that, if the fossils contained in the rocks constituting the surface in every district of Great Britain had been examined, it would be possible, by coloring a map of these islands in such a manner that all those parts whose fossils indicated their inferiority to the carboniferous formation should be blue, and all those which lay above it should be red, to indicate at once to the miner where his search for coal might possibly be successful, and where it must necessarily fail. And, furthermore, if the fossils on which the coloring was based were placed in a museum for public inspection, it would be open to every one to examine for himself the evidence on which the map stood, and to satisfy himself of the accuracy of this part of the work of the surveyors.

What is here supposed to be done with reference to this one set of beds—the carboniferous formation—has, in effect, been performed by the labors of the geological surveyors of Great Britain for all the strata which enter into the composition of the British Islands. The place where each constitutes the surface rock is marked by an appropriate color on the maps of the survey. The fossils which have served as the standards of comparison in determining the nature of the strata are open to general inspection in the Museum of Practical Geology. In one sense, therefore, the collection of fossils is simply the product of and key to the maps of the survey.

* PALAEONTOLOGY.—Derived from three Greek words, signifying "ancient" and "being" and "discourse." The science of ancient beings.

Important as it is, however, to the welfare and prosperity of the country that an accurate record should exist of the composition of its share of the earth's crust, whence the miner, the metallurgist, and the mineralogist extract so many products of the utmost value to man, and, indeed, indispensable to the maintenance of his present complex state of civilization to suppose that this immediate and so-called "practical" object of the collection is the only, or even the most important, end that it subserves, would be as great an error as that of the barbarous Oriental, who sees nothing but a convenient stone quarry in those massive pyramids, on whose walls the instructed Eastern traveler reads the history of an ancient world, and learns the more, the more knowledge and capacity he brings to the inquiry. In truth, the history, not merely of one but of a series of ancient worlds, is written upon the rocks which compose the solid coating of the globe in signs the meaning of which is decipherable with far more ease and certainty than that of hieroglyphic or cuneiform inscriptions; or we might say that, as it is the custom in these times to deposit the coins and medals of the age under the foundation stones of a building, so the Great Artificer has, as he laid each course of stone in the world's foundations, deposited coins and medals of His striking, the remains of the then existing system of organic life, the bones and shells of the contemporaneous living beings.

But a history in an unknown tongue can be profitable only to those who will take the trouble to acquire a knowledge of the construction of the language, and of the signification of its words and signs. Now, natural history, or the science of the structure and habits of living beings, is the grammar and dictionary of the language of fossils. To understand all that fossils teach, natural history must have been the study of a life; but a clear comprehension and careful recollection of a few of its simpler principles will be sufficient to enable a person of intelligence, unversed in science, to apprehend the wider bearings of the collection. To afford this assistance is the sole object of the present explanatory preface. It is intended to awaken even a casual visitor to a sense of the profoundly interesting problems which the collection forces upon our consideration; to enable him to comprehend how it is that the naturalist reads here, as plainly as if it were stated in to-day's paper, and with considerably more faith than he would place in any mere human affirmation, that the earth has undergone a great series of changes, stretching over enormous periods of time; that its living population has not always been what it is now, but that the present kinds of animals and plants have been preceded by others widely differing from them, and these by others, and so on, for an indefinite series of alterations; that these changes have been accompanied by constant alterations in climate and in the level of the land and sea; finally, that the period of time of which these records furnish the history is inconceivably immense.

These are weighty articles of belief, and nothing can seem, at first, to be less likely than that the accumulation of oddly marked and shaped stones, which are visible on the shelves around, should contain abundant evidence of their validity and truth; but so it is. How it is, will be rendered clear by what follows.

II.—Brief exposition of those principles of natural history which are of the most importance to the understanding of fossils.

It has been stated that natural history is the key to palaeontology, and hence, before attempting to learn the meaning of fossils, it is necessary

to be acquainted with those principles of biological science which bear most directly upon the subject:

1. The most important of all the generalizations of natural history, and, indeed, one of the most brilliant additions which the progress of modern science has made to human knowledge, is the law that all animals and plants are associated and arranged according to certain fixed laws.

Thus, to select an example from the animal kingdom: There is an immense variety of hoofed ruminating animals, antelopes, sheep, oxen, deer, giraffes, camels; but notwithstanding the extreme difference in the aspect of these well-known creatures, the anatomist discovers that they exhibit a great number of common characters. Thus—

a. All possess a backbone, or vertebral column, separating the great centers of the nervous system from those of the alimentary and circulatory apparatus; and the latter is situated on the ventral, front, or downward face of the body; none have more than two pairs of limbs; the chief central nervous system is not pierced by the alimentary canal.

b. All have a heart with four cavities; possess lungs and a midriff or diaphragm; and have two facets on the hinder part of the skull, for articulation with the foremost bone of the spinal column. In all, each half of the lower jaw is in a single piece, and is articulated directly with the skull by a convex head; they all possess mammary glands for suckling their young.

c. The teeth are in all more or less deficient in the front part of the upper jaw; they all possess complex stomachs, and not more than two completely developed long bones in the middle region of the fore and hind feet.

It would be easy to make a drawing embodying all these peculiarities, and that drawing would stand in precisely the same relation to the group of "ruminants" (technically called "*Ruminantia*") as the ground plan of a single house does to the street which the architect means to build of houses of that size and general form. The superstructure of each house may, if the architect pleases, be totally different in style, without in any way interfering with his general plan; and similarly, in each particular ruminant, the common plan is preserved, while the details of the "elevation," the size, the figure, the proportions, the ornamentation in the way of color and horns, vary to an immense extent.

Having thus acquired a notion of the "common plan" of the ruminantia, it will be found, on turning to other equivalent groups or "orders" of the *Mammalia*, (or animals which suckle their young,) that a corresponding common plan may be found for each; and when all these common plans are compared together, it will be discovered that there are certain respects in which they agree. All mammalia, in fact, possess the anatomical characters enumerated under the preceding heads *a* and *b*. Hence, a drawing exhibiting these features would serve as a "common plan" of the mammalia, and the common plans of the orders of mammals, ruminantia,* carnivora, &c., might be regarded as modifications of the plan of all mammals in the same sense as each ruminant is a modification of the common plan of all ruminants. But now, if we were to extend our researches further, and compare mammals with birds, reptiles, amphibia, and fishes, we should discover a still more remarkable fact, viz: that all these creatures, and only these of all living things, possess the character enumerated under the first head. Hence, a drawing or diagram embodying these characters would represent the common plan of

* Strictly speaking, the group *Ruminantia* is only a part of the modern order *Artiodactyla*, but it was convenient here to use the term in its old sense and value, or rather sub-order *Artiodactyla* of the order *Ungulata*.)

these animals, which are collectively termed the *Vertebrata;* and it would stand in the same relation to the common plans of birds, mammals, reptiles, amphibia, and fishes, as the ruminant plan did to oxen, sheep, and antelopes.

By carrying investigations of this kind into the rest of the animal kingdom it has been shown that every animal whatsoever is a modification of one or other of five great common plans—the plan of the *Vertebrata*, that of the *Annulosa*, that of the *Cœlenterata*, and that of the *Protozoa*. This division of the animal kingdom is not generally adopted in this country; that most prevalent recognizes the branches *Vertebrata*, *Articulata*, *Molusca*, *Radiata*, and *Protozoa*.

It is most important, however, not to form a wrong idea as to the real import of these "common plans." We must regard them simply as devices by which we render more clear and intelligible to our own minds the great truth that the parts of living bodies are associated together according to certain definite laws. Why it is that an animal which suckles its young should invariably possess a double articular surface at the back of its skull, should have the articular surface of its lower jaw convex or flat and not concave, and should always be provided with hairs and never with feathers, we know as little as why the earth turns from west to east, and not from east to west; but if the morphological law which expresses this invariable coexistence, or correlation, of organic peculiarities has been as regularly verified by our experience as the astronomical law, we may, for all practical purposes, reckon as securely upon the constancy of one relation as upon that of the other.

It is, indeed, remarkable to how great an extent we may depend upon these laws, and how seemingly unimportant, and in the present state of physiology inexplicable, many of the most constant correlations of animal parts are. Thus the profoundest of "teleologists"* will, probably, hesitate to attempt to account, by any physiological reasoning, for the above-stated invariable occurrence of true hairs in those animals only which suckle their young and have two occipital condyles; but, nevertheless, if a single hair be placed before a naturalist he will be able, in many cases, not only at once to decide that the animal to which it belongs possesses a backbone, has four limbs, suckles its young, has a heart with four distinct cavities, possesses lungs; but he may be able to go into minute details as to the structure of its brain, and the arrangement and number of its teeth. How does he know these things? Simply because experience teaches him that the structure of the hair in question is found as a constituent part of only one particular plan of organization, and, therefore, may be depended upon as an indication of all the other peculiarities of that plan. Just as when a particular characteristic fossil is found we may predicate what other fossils will be found in the same bed, without having the least idea of the why and the wherefore of the association; so the apparently trivial and unimportant hair indicates, we know not why, all the other structural peculiarities which experience shows to be associated with it. We shall find the application of these truths by and by in considering the methods by which fossils are determined.

Important consequences flow from the fact that the forms of living beings are modeled upon common plans, and from the kind of relation which exists between any actual form and its plan. Thus the vertebrate plan, as has been seen, undergoes five modifications, each of which constitutes the common plan of a large assemblage of animals—of mammals,

* TELEOLOGY.—The doctrine of final causes. "Teleologist," one who seeks for the final causes of phenomena.

of birds, of reptiles, of amphibians, and of fishes; and if we select any of these subordinate plans we find it again modified so as to constitute the plans of the minor subdivisions of these great assemblages. The reptilian plan is modified in one way to form the plan of the turtle tribe, in another to constitute that of the crocodiles, in another that of the lizards, of the snakes, and so forth. And, in like manner, the common plan of any great division of the animal kingdom is seen, in nature, to be modified into a series of more and more altered and specialized plans, each of which is common to the members of a progressively smaller subdivision of the group, until at length we arrive at the smallest assemblage of beings which can be said to possess a particular common plan; or, in other words, which exhibits characters common to all its constituents, and not possessed by those of any other group.

It is by reason of these singular relations among the forms of living beings that what is termed a "natural classification" is possible. In the ordinary business of life, whenever it is necessary to recollect and have at command a multiplicity of objects, we "classify" those objects; we arrange them in groups or packets distinguished by particular marks and having a particular order. Thus it is that the merchant arranges his wares, the librarian his books, the lawyer his papers; and the naturalist, in like manner, would find it utterly impossible to grapple with the details of the two or three hundred thousand distinct forms of living beings, which are the object of his study, unless he could in some way classify and arrange them.

Now the aim of classification may vary. Many persons imagine that natural history is the knowledge of the names which have been affixed to animals and plants by men of science; and the wish of such persons is to have a classification so contrived as to enable them, with the least possible trouble, to ascertain what name has been affixed to an object, or, better still, to determine that no name has been given to it, when they have the satisfaction of baptizing it themselves. These "naturalists," necessarily, desire in a classification only a good index and dictionary of the names of animals and plants, and it matters not by what marks they designate their groups so long as those marks are easily discoverable and readily remembered. Thus, plants might be divided according to the number of stamens in the flower, while animals might be classed according to the number of their teeth, the shape and number of their legs, &c.; and arrangements of this kind, if skillfully made, might have no small value and use in helping us to discover what animals and plants are, and what are not known, but it is clear they would be purely arbitrary; there would be no necessary relation between the members of the various groups beyond the single point in which they agree; in other words, the classification would be "artificial" and not "natural."

But the low conception of the objects of the science of natural history, from which such artificial classifications flowed, has given place to other and higher views, and with it all artificial systems have become exploded, or relegated to their proper place as mere aids to the memory. The naturalist of the present day, in fact, stands to him of the past in the relation of a Niebuhr, a Hallam, or a Guizot, to the gossiping compiler of a *chronique scandaleuse*, or, at best, to a Froissart or a Burnett. Without despising the importance of a knowledge of the names and habits of living beings, he sees beyond this, and overruling it, a higher and a nobler aim—the investigation of the laws of life, of the principles discoverable amid the multiform structures of living beings, and of the relations in which they stand to one another and to the surrounding universe.

For such objects an artificial classification is useless, if not obstructive.

The laws of life can only be obtained by observation of the facts of life and generalization from those facts, and the philosophical naturalist seeks that classification which shall best enable him to remember facts and generalizations already won, and shall most efficiently assist him to obtain others.

As Cuvier has well expressed it, modern classification endeavors to throw the facts of the structure of living beings into the fewest possible general propositions. Each living being, therefore, has been compared with all others, and those from which it is not separated by any constant difference are grouped together as one "species." The different species have next been compared, and those which agree in some one or more characters, while they differ from all others in these characters, are arranged into a larger group, called a "genus." By a like procedure, genera have been grouped into "families;" these into "orders," orders into "classes," and classes into "subkingdoms," which last are the primary subdivisions of the animal and vegetable "kingdoms" respectively.

The resemblances and differences upon which the groups are founded, being based on a comparison of the whole organization of living beings, are thorough and fundamental, and, as it were, indicated by nature herself. Hence this mode of classification has been termed "natural," in contradistinction to those previously referred to, the divisions of which are founded on insulated and superficial relations.

But it is obvious that if animals and plants were not constructed upon common plans, it would be impossible to throw them into groups expressive of their greater or less degree of resemblance, such as those of the natural classification. In fact, the doctrine of "common plan" and of "natural classification" are but two ways of expressing the great truth, that the more closely we examine into the inner nature of living beings, the more clearly do we discern that there is a sort of family resemblance among them all, closer between some, more distant between others, but still pervading the whole series.

There is yet another way in which this doctrine has been expressed. In every group there is some average form, some form which occupies a sort of central place, around which the rest seem to arrange themselves; and this form may therefore be taken as the representative of the group, as the nearest actual embodiment of the common plan. Such a form is commonly called the *type* of the group; and in this sense an antelope might be termed the type of the *Ruminantia;* a dog of the *Carnivora.* It is in this sense that the word "type" will be used in these pages; but it is proper to remark that the term is not uncommonly applied to the most characteristic and marked form of a group. In this sense a cat rather than a dog would, perhaps, be selected as a typical carnivore.

The phrase "family resemblance" has been used above, and it, perhaps, expresses better than any other the sort of likeness which exists among the members of a natural group; specific and generic alliance having the same sort of relation as brotherhood and cousinhood. But it is important to remember that the classification of animals and plants stands on its own basis, and is entirely independent of physiological considerations. For the purposes of the classifier it is wholly immaterial whether, as some maintain, "species" are immutable and have taken their origin independently of one another, directly from the hand of the Creator; or whether, as others think, they are indefinitely modifiable, and have all resulted from the changes induced by external influences upon some common stock. If all forms of living beings were fossil, and we knew nothing about life, the natural classification of animals and plants would be exactly what it is now; except as it might be affected by the resulting

deficiencies in our knowledge. At the same time, the inquiry into the permanence or modifiability of species is, in itself, of the highest importance and interest; and it will be necessary to advert to the bearings of the little definite evidence we at present possess upon the subject in some of the following pages.

(Here follows in the original, on pages xix—xxix, a review of the sub-kingdoms and classes of animals; but as there are several disputed points, and as the author himself has since modified his views, they are not reproduced.)

The *Protozoa*, as a whole, are evidently simpler in structure and less variously endowed than the *Cœhlenterata;* the *Cœhlenterata* than the *Mollusca* or *Annulosa;* and none of the last approach either birds or mammals in complexity.

Again, a lamprey is a simpler animal than a horse, a worm than a bee.

These indubitable facts are commonly expressed by the phrase that the simpler animals are lower and less perfect than the higher, and this indeed, in one sense, they truly are. But we should greatly err in supposing that *less perfection* implies *imperfection;* or in imagining that the less perfect animal is in any way unfitted for the conditions under which it lives. Were it so, its race would necessarily sooner or later cease to exist. If we look closely into the matter, it will be found that by "less perfect" and "low in the scale of life," one of two things is meant, either firstly, that the creature of which the assertion is made is a less complicated apparatus; or secondly, that the parts of which it is composed differ from one another comparatively little in form and structure.

It is worth while to consider each of these cases more fully. Every animal (indeed it might be said every living thing) has in the gross the same kind of work to do: it has to take in the food necessary for its support; it has to change this into other products and to mold them into its own peculiar form. Lastly, it has to exhibit that kind of reaction upon external impressions which is known as "irritability." Absorption, metamorphosis, and irritability, these are the three great "functions" of all animals.

Now the difference between one animal and another, as to the mode in which the functions are performed, is very similar to the difference which exists between one human society and another, as to the mode in which the affairs of life are carried out. All human wants may be summed up in two words: sustenance and freedom; but the mode in which men secure the satisfaction of their wants varies with the perfection of their social state. In savage life every man procures his own food, and relies for his security from constraint upon the strength of his own arm. But this state of things is manifestly incompatible with any great advance, either in those arts which minister to the physical, or in those which satisfy the moral nature. If a man has to find his food every day he will not spend much time in cooking it; and if he is liable to be attacked by an enemy at all hours, he is pretty sure never to attain to much eminence as a painter or a violinist. By the necessity of the case, then, where every man has to do everything for himself, nothing will be done very well; no man will be much better than another, and none will be very far above the level of mere animal existence.

Contrast this state of things with that which obtains among the active members of a highly civilized society, such as our own. Each devotes himself to one occupation, striving to carry out that in the best possible manner; and trusting to others who devote themselves to other specialities for the satisfaction of all the rest of his wants. There is a "division of labor;" the wants of mankind are split up, as it were, into

a hundred subdivisions, and every man charges himself with the satisfaction of one of these subdivisions, hoping that, in exchange, his own ninety-nine wants will be satisfied by others. So that, in one sense, a hundred civilized men may be said to be the equivalent of but one savage; while, if, on the other hand, we regard the nature of the products of civilization, and balance the sum of the work done on each side, the advantage on the side of civilization is infinite.

It is precisely this division of the physiological* labor, the organism, which constitutes the first of the two great kinds of difference between animals. Some *Protozoa* have no definite aperture for the taking in of food, no muscles, and no limbs. Every part of the body-wall may serve in turn as mouth or locomotive organ. In others there is a mouth, but no definite alimentary canal, and the contractile locomotive apparatus is limited to one part of the body. In the *Cœlenterata* the mouth and digestive cavity are permanently appropriated to that office, though not separate from the rest of the cavity of the body. The motor organs are still more definite and serve as organs of prehension and offense. In the *Mollusca* the digestive cavity is permanent and completely separated from the walls of the body. A blood system is developed to carry the nutritive matter to all parts of the body. Another portion of the organism is converted into muscle, and can do little but contract; another has nothing to do but to form shell; another, the nervous system and organs of sense, is charged with the sole duty of putting the different parts of the organism in relation with one another, and with the external world. Thus, in the mollusk, each part of the organism is charged with a special function, and, to the same extent, has become dependent on others. The stomach that digests depends on the blood for its own nourishment. The muscle that enables the animal to seize its prey would perish without the aid of the stomach and the blood, and would be ineffectual without the nervous system which guides it. The mollusk does no more in the long run than the *Amœba;* it absorbs food, it modifies it, and it exhibits irritability, but the manner in which it does all these things is infinitely superior, and enables it to display powers of which the *Amœba* exhibits no trace.

It is needless to pursue the argument further, or it would be easy to show that the difference between man and the mollusk, as physiological machines, is of the same kind as that between the mollusk and the protozoön; in short, *physiological* perfection is in proportion to the division of the labor of the whole organism among organs specially adapted to particular offices.

The other sense in which perfection is attributed to living beings is morphological.† The *Mollusca*, as a whole, are more perfect than the *Cœlenterata*, because they exhibit a greater number of specialized and diversiform parts and organs, quite irrespective of the functions of those parts and organs; and the *vertebrata*, in their fundamental character, the possession of a true primordial internal skeleton, exhibit a greater complexity of structure than any mollusk, or any annulose animal.

It of course usually happens that physiological and morphological complexity go hand in hand, but it should be remembered that the conjunction is not a necessary one. The lowest vertebrate animal, for in-

* PHYSIOLOGY.—The science which treats of the forces exerted by living beings irrespective of their forms; except so far as these contribute to the exertion of these forces.

† MORPHOLOGY.—The science which treats of the forms of living beings without regard to their functions.

stance, is in some morphological respects more complex than the highest mollusk, but physiologically it is less so.

One other commonly-used phrase, expressive of the relation between different kinds of living beings, requires explanation, as its employment in an erroneous sense has led to grave errors. There is a current impression that the lower animals correspond with the embryonic conditions of the higher; that, in the course of their development, the lower animal advances up to a certain point and then stops, while the higher goes on.

This notion, however, is entirely incorrect; there is no known adult animal which would be regarded by any naturalist as of the same species with any early condition of another animal, if the two were submitted to him for comparison. In no stage of their existence would a competent naturalist regard embryonic reptiles, or mammals, as fishes; in no stage would he take an insect for a worm, or a cuttlefish for any lower mollusk. The whole of this idea, the truth of which has been assumed so often in geological speculations, rests upon a misunderstanding of an undoubted fact, namely, that there is a time in the development of each when all members of a sub-kingdom resemble one another very closely, and that they remain alike for a longer or shorter period according to the closeness or remoteness of their affinity. Thus there is a time when the embryo of a fish could be hardly distinguished from that of a reptile, a bird, or a mammal. But the embryo fish sooner becomes unlike a mammal than the embryo reptile or bird; and the embryo quadrupedal mammal remains longer like a human embryo than does that of a fish or reptile.

Thus all animals in their youngest condition have, for a longer or shorter time, a similar form, from which each diverges to take its special configuration; if one may so say, they travel along the same road for a shorter or longer distance, and then each goes aside to its own place. But this is a very different matter from any one form being an arrest of development of another. Of two men traveling together along the great North road, one may be going to Newcastle and the other to York. But it would be a very insufficient and erroneous description of the journey of the one to say that is was merely that of the other cut short.

3. The next great principle of natural history of which some definite notion must be obtained, is the doctrine of what is called the "distribution" of living beings. It is a matter of familiar experience that elephants, lions, and rhinoceroses are not at present indigenous in Great Britain; and humming birds, crocodiles, and flying fish are as strange to us as are the white bear, the ermine, and the musk ox. Nevertheless, the latter animals are found abundantly in more northern latitudes, while the former swarm within the tropics. Were any one to visit the countries in which the white bear and the crocodile respectively abound, he would discover that there was a certain northern limit beyond which the crocodile was never seen; and, on the other hand, that the white bear never ranges south of a given latitude. In other words, the white bear and the crocodile are found within, or are distributed over, certain limited spaces of the earth's surface, and lines drawn on a globe so as to inclose these spaces, would indicate the "geographical distribution" of these animals.

There are hardly any species of animals and plants which are not in like manner confined within limited geographical areas, and hence if we were to set out from England, and travel either due south or due north,

we should find that a gradual change would take place in the fauna* and flora of the countries traversed, their inhabitants differing more and more widely from those of this country, the more nearly they approximated either the pole or the equator. Nor is this result other than might be naturally expected, for we know how closely dependent the health and strength of animals and plants are upon the amount of heat, light, and moisture to which they are exposed; and in traveling due north or due south, these climatal conditions necessarily become very greatly altered. A corresponding change in the flora and fauna is observed when, in a mountainous country, we ascend from the plains to the line of perpetual snow; and the animal and vegetable inhabitants of the sea in like manner vary in character and abundance at different depths. But these cases also seem readily intelligible, for elevation has much the same effect on climate as northing; and every fathom of increased depth in the sea corresponds with a certain diminution in the amount of light and a certain alteration in temperature.

Again there seems to be no difficulty in understanding why, as we find to be the case, terrestrial animals and plants differ from those whose existence is spent in the water; nor why, among purely aquatic creatures, the inhabitants of fresh water are usually widely different from those of the sea. The discrepancy in form seems quite in harmony with the discrepancy in external circumstances.

But there are some other facts connected with distribution, the cause of which is by no means so obvious. If the traveler, instead of moving to the north or to the south of this country, journeyed east or west, keeping as nearly as possible within similar climatal conditions, he would, nevertheless, still find that the successive faunas and floras through which he passed were widely different; and if a voyager were to circumnavigate the globe between the parallels of 40° and 60° S., touching at ports in the continents of Africa, Australia, and America, the differences between the indigenous animals of each country would be immense, and altogether out of proportion to the changes in climatal conditions.

The globe, then, may be marked out by boundary lines, some of which run northerly and southerly, and others easterly and westerly, into a number of districts or "provinces," each of which is characterized by a peculiar assemblage of animals and plants. And again, each district might be subdivided by lines parallel with the horizon, into zones of depth and of height, in each of which a certain group of this assemblage would flourish. It must be remembered, however, that neither zones nor provinces are capable of a strict limitation, there being always a border-land between every two, in which the inhabitants of both are mixed.

The phenomena of distribution in depth are particularly worthy of attention, from their bearing on geology; for it is obvious that if we are enabled to lay down certain rules with regard to the depth at which particular forms live, we shall be able, when we find these forms in an ancient sea-bed, to form a judgment as to the depth of that sea-bed, and hence, in many cases, to gather valuable indications as to the proximity or distance of dry land. Every one who has walked along the sea shore is familiar with certain forms of life—barnacles, limpets, periwinkles,

* The term "*Fauna*" is applied to the whole of the animal inhabitants, "*Flora*" to the whole of the plants, of a district or country. Thus, the fauna of Africa means all the animals found in Africa; the flora of India, the flora of Kent, means all the plants found in India and Kent respectively. In speaking thus it will be understood that the "indigenous" animals and plants, or those which naturally exist in a country, are alone referred to.

dogwhelks, shore crabs, which cover the rocks between high and low water marks. During calm weather he might imagine that these constituted the chief inhabitants of the sea; but should a heavy gale of wind set in landwards, he is soon undeceived, for the waves, tearing up the sea bottom at depths greater than those which are ordinarily exposed by the recession of the tide, cast on shore vast numbers of new creatures, such as whelks, sandstars, corallines, and great masses of seaweed, with whole colonies of animals attached to them, which habitually remain in the deeper regions.

Not satisfied with such accidental revelations, modern investigators have systematized and extended the explorations of marine depths by means of the use of the "dredge," a simple apparatus, long used by oyster fishermen to procure their merchandise, and, of course, equally applicable to the dragging up of other inhabitants of the floor of the sea.

It results from a long series of such observations that at least five zones, each characterized by peculiar forms of animal or vegetable life, may be distinguished at different depths. They are, 1st, the "littoral" zone, corresponding with the interval between high and low water marks; 2d, the "circumlittoral" zone, extending from low water mark to the lowest limit at which the coral-like plant *Nullipora* is found, a depth, in our latitudes, of between fifteen and twenty fathoms; 3d, the "median" zone, characterized by the abundance of *Polyzoa* and *Sertularidæ* which it exhibits, and by the predominance of carnivorous forms among its *Mollusca;* it extends in our seas to about fifty fathoms; 4th, the "inframedian," and, 5th, the "abyssal" zones lie beyond this, but can be hardly said at present to be well defined. It is in them that our corals and *Brachiopoda* flourish. Much attention has of late been paid to the investigation of the deep sea animals and plants, and numerous species have been found at very great depths. As might have been expected, from the greater uniformity of physical conditions at such depths, the same species have been found at very distant localities, and exhibit a wide geographical range in latitude as well as longitude. Another peculiarity more marked even than could have been anticipated is the affinity and even identity of many species with tertiary and cretaceous forms.

The extreme limits of vegetable and of animal life are not known. The higher *Algæ*, such as sea weeds and *Nullipora*, are, in our own latitudes, not found below twenty fathoms; but it is not improbable that the *Diatomaceæ* flourish at the furthest limits of life.

Both the number of species and the number of individuals of animals diminish at greater depths. A greater profundity than two hundred fathoms is not to be reached within a very considerable distance of any part of the British coasts; but in both northern and southern seas living animals have been drawn up from more than three hundred fathoms (or 1,800 feet) below the surface. It is important to remark that the inhabitants of these and still greater depths, however diminished in number, do not appear to become degraded in organization, but consist of *Crustacea*, *Echinodermata*, *Gasteropoda*, *Lamellibranchiata*, *Polyzoa*, and *Actinozoa*, of types quite as elevated as those which are found in more shallow waters, but they are frequently less brilliantly colored than the latter. While the laws of distribution, as they have been at present determined, therefore, do not enable us to say precisely at what depth living animals can no longer exist, nor even to trace the influence of depth in modifying their forms, they seem, nevertheless, to point to certain assemblages as characteristic of certain ranges of depth. For instance, limpets and periwinkles appear to be absolutely characteristic of shallow water, being

found but a very short way beyond tide marks. The lower limit of the plant *Nullipora*, on the other hand, seems to mark in all seas the line of demarcation between moderate depths (under one hundred fathoms) and great depths.

We must remember, however, in attempting to apply these generalizations, that as yet distribution in depth has hardly been fairly worked out, even in temperate latitudes, and that before we can safely enunciate laws of general application, a vast number of observations must be made in both tropical and arctic climates.

The fact of the apparently capricious limits which have been assigned to many animals has been alluded to above. That all animals are adapted to the conditions in which they live is a truism, for if they were not so adapted they would not live, but die; but the strange fact is that we do not always find animals in those conditions for which they are adapted. At the present day millions of horses run wild over the Pampas of South America, and these great plains are overspread with a peculiar kind of thistle; there can be no doubt, therefore, that the climatal and other conditions of this part of the American continent are eminently favorable to both horses and thistles. Nevertheless, at the period of the discovery of the Americas, neither the horse nor the thistles existed in these regions.

In like manner, eighty years ago, neither horse, nor ox, nor sheep grazed the wide pastures of Australia; now they flourish and run wild there. The same is true of New Zealand. The little fresh-water muscle, the *Dreissena*, now so common in our canals, having swarmed over the whole country, is a recent importation from Eastern Europe. Conditions most favorable for its existence have existed for ages, and yet it only now reaches them artificially. However trite may be the assertion, therefore, that animals are fitted for their conditions, the converse proposition, that conditions imply the existence of creatures fitted to flourish in them, is manifestly untrue.

Again, the existing distribution of animal life furnishes good grounds for exercising the greatest caution in reasoning from the population of one area, however vast, to that of another. A naturalist might be perfectly acquainted with the indigenous animal inhabitants of all South America and Australia, and yet not know that there were such things in the world as the elephant, the rhinoceros, the hippopotamus, the giraffe, the lion, the tiger, the horse, the ox, the sheep, or the goat. He might be fully acquainted with the population of all the enormous area which contains Australia and the Pacific Islands, and yet not only be ignorant of the animals just mentioned, but might never even have heard of bears, cats, monkeys, ruminants, sloths, or ant-eaters. Finally, the exclusively African naturalist might fairly conclude from his own experience that great quadrupeds abound everywhere, and that there are no such things as kangaroos or opossums.

The commonest facts in distribution, therefore, teach us that it is never safe to apply conclusions based upon the investigation of a limited area, however large, to the animal inhabitants of the rest of the world.

There is yet another caution necessary in reasoning from the facts of distribution. It should be well borne in mind that the connection between a given form and the conditions in which that form flourishes is, in the great majority of cases, unknown to us. The laws of distribution are for the most part purely empirical; they are merely the expression of observed facts, of the reason of which we know nothing. If we observe species A always in a warm climate and species B always in a cold one, we may conclude if we find specimens of A and B that the climates in

which they flourished were respectively warm and cold. The force of the conclusion will depend upon the extent of our previous observation with regard to A and B. In practice, and within certain limits, such a conclusion is probably valid, but it is a very different matter if the argument is put, as it more commonly is, thus: Species A and B are found respectively in hot and cold climates; therefore species *a*, which is very like A, though not the same, and species *b*, which is very like B, though distinct, indicate that the climates in which they flourished were respectively warm and cold.

This argument, it is obvious, is only valid on the assumption that certain amount of similarity of form implies similarity of necessary conditions; and the question immediately arises: How much similarity of form implies how much similarity of condition?

In the present state of science no definite answer can be given to this question. It is not understood why some genera are well-nigh universal in their distribution, others limited in their area. No comparison of the osteology of the arctic fox and of the jackal, of the polar bear and of the black bear, of the musk ox and of the buffalo, would enable the anatomist to tell which of these species inhabits an arctic, and which a warmer climate. And on the other hand, though the existing species of hippopotamuses, rhinoceroses, and elephants are now exclusively inhabitants of warm climates, it is certain that very similar species formerly flourished in climates at least as cold as that of England, if not much colder.

That these difficulties beset the enunciation of laws of distribution of general application, indicates what is tolerably certain on other grounds, that the existing arrangement of living beings on the surface of the globe is a complex result, the product of the interaction of a number of distinct causes. It is pretty clear, indeed, from what we know of life, that the presence or absence of any particular living being, on any given spot of the earth's surface, must depend on these conditions:

1st. The mode and place of origin of that kind of living being.

2d. Its powers of voluntary migration.

3d. The extent to which it has undergone involuntary migration in consequence of changes in the distribution of sea and land, currents, &c.

4th. The range of climatal and other conditions under which alone it can exist.

If we had these data for each species, its distribution would be a matter of calculation. But unfortunately they are not yet ascertained for any species whatsoever; nor is there, with regard to one or two, that agreement among men of science as to the probabilities of the case which would be desirable.

Thus, respecting the first condition, no one has ever witnessed the origin of a species, nor is there any scientific evidence as to the mode or place of origin of any living thing.

As to the hypothetical views, all the possible alternatives have their advocates. There are those who suppose that all living beings were created at once, in one spot, whence they have subsequently migrated; but persons of sound intellect, acquainted with the facts, usually attach themselves to one of two other views. On the one hand, some conceive that all living beings were created as we find them, and where we find them; or that, at any rate, they are the descendants of a stock created within a distance not greater than can be overcome by the voluntary or involuntary migration of the species. Those who entertain this view usually suppose that a species once created can only be modified to a very limited extent.

On the other hand, their opponents maintain that there is no evidence that species were created as we find them, but that there is reason to believe that all living things are the result of the gradual modification of one or more primitive forms.

Passion and the *odium theologicum* are too often allowed to enter into the discussion of these views. The triumph of either, except so far as it is the triumph of truth, is to the man of science, however, a matter of profound indifference; and in this spirit the arguments on both sides are thus shortly summed up:

a. Those who maintain the first view urge that all evidence tends to show that, in the ordinary course of things, living beings can only take their origin from pre-existing living beings; so that, even if the indefinite modifiability of species were admitted, it would yet be necessary to suppose a direct creative interposition in order to account for the first germ of all; and if we admit one direct interposition, it is said, there is no difficulty in admitting twenty or twenty thousand. To this it is replied, that, although there may be no greater difficulty in the one case than in the other, yet the assumption of creative acts, being in reality nothing more than a grandiloquent way of expressing our ignorance of the real connection of the phenomena, and our incompetence to conceive their origination, every reduction in the number of such assumptions is a clear gain to science.

It is furthermore urged that the direct creation of a species is an occurrence which not only has no scientific evidence in its favor, but is, in the nature of things, incapable of being supported by such evidence. For, suppose that in a glass of water, perfectly free from a trace of organic matter, a new species of fish were suddenly to make its appearance before the eyes of half a dozen naturalists, not one of them would believe, or would be justified in believing, that this was a direct creation out of nothing. Philosophically it would be illogical, and religiously it would be mere superstition to believe that which is in direct contradiction to our universal experience of the modes of action of the Creator.

b. It is affirmed that, in some cases, animals and plants of the same species inhabit such completely separated regions that their origin, except by independent creation, within their present area is inconceivable. One of the strongest cases of this kind is that afforded by a marine crustacean, sometimes seen in our fish markets, the Norway lobster, (*Nephrops norvegicus.*) This animal is found on the shores of Norway and of the northern parts of the British islands, but not on our southern shores, nor on the Atlantic coast of France, Spain, or Portugal; it reappears, however, at Nice in the Mediterranean, and abounds in the Adriatic about Venice.

There appears to be no doubt that the northern and the southern forms are specifically identical, and it is naturally asked, how could these isolated detachments of one species have migrated to such widely-separated points without leaving some colonies on the only road which is open to them, viz., the western shores of Europe? And if their present distribution is not to be accounted for by migration, how is it explicable, except by supposing that the stock of each detachment was created where we find it?

Were the limits of the land and sea fixed and unchangeable, were there no such things as geological change, the problem might seem to be insoluble. But the instability of the land and the consequent incessant alteration of dry land and deep sea at the very same points of the earth's surface, are the first lessons of the student of geology. This being the case, however, the argument at once loses its force; for if by the submergence of Central Europe the Mediterranean and the North

Seas ever communicated, the *Nephrops* would readily have spread from Norway to the Adriatic, or *vice versa;* and when the central mass of Europe rose again, the area of its distribution would be cut in two, and the northern and southern fragments only left.

That this is the explanation of the apparent anomaly would be proved if *Nephrops norvegicus* were found fossil in any of the strata constituting the present land of Central Europe. So long as this is not the case it can only be regarded as hypothesis more probable than that of special creation at two points, and hence excluding the necessity of adopting the latter.*

Many cases of distribution which have been supposed to be similar to that of *Nephrops*, and adduced as such by the advocates of many centers of creation, have been shown to be not really of the same nature, the widely separated forms not being in reality of identical species.

c. The great question, however, upon which the two schools of naturalists divide is: Are species permanent? In other words, is it possible that any conditions operating through any amount of time upon any number of generations of a species A, shall give rise to a distinct species B?

In this, as in all other instances where thinking men entertain flatly contradictory opinions, the difficulty of coming to a mutual understanding appears to arise in a great measure from the want of a clear apprehension of one another's meaning. In the present case it is probable that no two persons attach precisely the same signification to the word "species."

Most naturalists admit, indeed, that species have a distinct physiological character, viz: that the intermixture of two species will not produce a fertile race, even if it gives rise to any progeny at all; but, unfortunately, this test is, from the nature of the case, practically inapplicable, not only to the great majority of living animals and plants, but to all fossils.

In practice, therefore, the naturalist is obliged to neglect the physiological characters of a species, and to confine himself entirely to those which can be founded on form and structure. In this sense a species is the smallest group to which distinctive and invariable characters can be assigned.

If, to use a seemingly paradoxical expression, all living beings were extinct—if they were represented by a limited number of fossils, and lay before us as things to be arranged and classified, the practical application of this definition of species would have no difficulty. Sooner or later the whole organic world would be sorted out into the smallest parcels which could be characterized by a definition, and these would be "species."

It is obvious that the task would be equally easy were all living beings absolutely immutable; if every member of a species were exactly like its fellows, and if all progeny precisely resembled its parentage.

If every dog, for example, were precisely like every other dog, and every puppy exactly similar to its parents, there could be no difficulty about defining the species dog, nor could there be any hesitation in deciding whether a given animal belonged to the species dog or the species wolf.

Unfortunately for scientific ease, no such immutable forms exist in nature. Like everything else in the world, a living being is a compro-

* Species of the genus *Nephrops* have, curiously enough, been found fossil in Central France (department of the Yonne) at a point about half way between the northern and southern area of *N. norvegicus.*

mise, a resultant of all the forces which act upon it; and though, like a planet, it tends with an immense force to move in a course of its own, yet, like that planet, it is affected and perturbed more or less by all surrounding conditions.

Hence, inasmuch as no two living beings can ever possibly have been subjected to precisely the same conditions, it is not wonderful that no two ever were, or ever will be, precisely alike; nor is it strange that species vary in proportion to the variety of the conditions to which they are exposed.

It is needless to do more than refer to facts which lie within every one's experience. No person is unaware of the difference in the result produced when two seeds from the same plant, or two animals from the same brood, are exposed to widely different conditions in respect of light, warmth, and nourishment.

In all such cases, however, the modification is limited in amount, and no modification of conditions will so mask the characters of the species as to prevent their recognition in either the stunted or the overgrown individual. For every individual, therefore, it can hardly be doubted that specific characters are permanent and immutable. Do what you will with a sheep-dog puppy, you will not turn him into a wolf.

It is obvious, therefore, that thus far the influence of conditions can be shown to have no appreciable effect in permanently modifying species; for, if the offspring of the modified individual were in all respects like its parent before the modification of the latter, it is clear that the whole influence of the modifying conditions would only bring it to the same point as the parent; that the modification in any number of generations would go no further; and that when the influence of these conditions was removed, the species would at once return to its primitive and typical form. Thus, suppose a pair of sheep-dog puppies could be converted into greyhounds by a peculiar course of food and training; for anything which has been yet stated they would produce puppies which would only become greyhounds under a like course, and if left to themselves, would resume their pure and unchanged sheep-dog character.

Now, in nature this is not the case, by reason of the great fact of hereditary transmission. Every living being is, it has been said above, the resultant of all the forces which act upon it; the statement is incomplete unless we add: and which *have acted* upon its parents.

The forces in question are divisible into two classes: the one more powerful, intrinsic, impressed upon the germ, and causing that germ invariably to tend toward the production of a given form; the other weaker, extrinsic, consisting of all those assisting, modifying, or even destructive influences which reside in the surrounding universe, and which are called external conditions.

For every individual living thing, this distinction into intrinsic and extrinsic forces is absolute; but the law of hereditary transmission obliges us to admit that it may not be so for a series of generations. For hereditary transmission means simply, that a modification undergone by a parent more or less affects its offspring—the offspring tending to reproduce that modification. Thus in the imaginary instance given above, the offspring of the modified sheep-dog, even if placed in entirely indifferent conditions, would have a tendency to assume greyhound characters. The intrinsic force of that germ, its tendencies, would be thus far modified by the influence exerted by external conditions on its parent. The operation of an extrinsic force on one generation may become in the next an intrinsic force.

But it is obvious that if once the influence of hereditary transmission in modifying the tendencies of the germ (and no one denies it) be admitted, it is very difficult to say where the modification of a given species shall stop.

Here, therefore, is the battle ground of those who admit and those who deny the indefinite modifiability of species. On the one side are adduced the two indubitable facts, firstly, that certain unquestionable modifications of one and the same species, such as the dog, are, as Cuvier says, more different than any wild species of the same natural genus; secondly, that the admission of indefinite modifiability reduces the production of species to the ordinary course of nature, and accounts equally well for all the phenomena with any other hypothesis.

On the other side are the equally unquestionable truths that specific characters are retained under even extreme modifying influences with great tenacity, and that artificially produced modifications tend, if left to themselves, to return, more or less nearly, to their primitive specific character. It may be doubted, however, if these propositions are really inconsistent with the doctrine of indefinite modifiability.

At present the evidence before the naturalist can hardly justify him in declaring his absolute adhesion to either view, but according as he inclines one way or the other, so will it be probable that his views as to the limits of species will vary. He who leans to the hypothesis of indefinite modifiability will tend to neglect, and he who inclines to that of the fixity of species will tend to exaggerate, minute differences. As the case now stands, those who wish to adhere to the golden mean must put their trust in common sense, a perception of the needs of science, and that sort of tact which can be gained only by incessant practical working at species.*

4. So much for those laws of natural history which help us to understand what the various forms of living beings are, and how they vary. The next most important question is, do animals and plants, as they die, perish and leave no trace behind, or what becomes of them?

The answer to this question must be different according to the particular kind of animal or plant to which reference is made. The fungus, which springs up in a night, dies, decays, and is swept away as rapidly; and the soft marine jelly-fish or worm may leave no more permanent traces of its existence. Carnivorous and herbivorous animals, again, destroy and efface all recognizable signs of the existence of multitudes even of those living beings which are, physically and chemically, better qualified to endure. Again, though it be a fact that the great majority of both animals and plants are provided with parts sufficiently hard and indestructible to resist the ordinary causes of decay for a very considerable time, nevertheless exposure to damp and change of temperature in the case of the remains of land animals, and the incessant wear and tear of watery action among aquatic creatures, would sooner or later destroy, or so deface as to render unrecognizable, the trunks of the hardest wooded trees and the most solid bones and shells; and this would take place in a space of time which, however long to us, is a very brief period, geologically speaking, were it not for the very simple but efficient preservative agencies which are brought into play by the very same causes.

The hard parts of terrestrial animals and the remains of land plants are, indeed, to a great extent destroyed by their exposure to the condi-

* It should be noted that these pages were written before the appearance of Mr. Darwin's book on the "Origin of Species," a work which has effected a revolution in biological speculation.

tions enumerated above; but it occasionally happens that accidental floods sweep them away into low grounds, hollows, or caves, where they rest and become covered up with the fine mud deposited as the waters subside; or living animals may be swallowed up in peat-mosses and in swamps; or their remains may be exposed to the action of springs highly charged with calcareous matter, and thus become coated with carbonate of lime; or the wind may envelop them in drift sand; and in all these instances they will be more or less effectually protected from further change.

The imbedding and preservation of the exuvia of those marine animals and plants which are not destroyed by the carnivorous and herbivorous races, on the other hand, is hardly a matter of chance, but must always inevitably take place. The sea is incessantly wearing away the shores against which it beats, and the shallow grounds over which its currents and tides race, undermining and cutting them away, and grinding the fragments down by their mutual friction into boulders, shingles, pebbles, sand, and mud. It then carries away the finer materials, and spreads them over the deeper and quieter portions of its bed, where they are arranged in successive layers, which gradually rise into banks of mud and sand. Brooks and streams, constantly bringing down similar materials from the higher grounds inland, add to these deposits, or form similar ones peculiar to themselves, thus giving rise to the "deltas" and the "bars" found at the mouths of most rivers. In all the quieter and not too deep parts of the sea bed, therefore, it is as if a constant though very slow rain of fine earthly particles were going on, and consequently every dead shell, every undestroyed bone, which is left on the bottom, is sooner or later covered up and protected from further destruction. Just as the showers of fine ashes which fell from Vesuvius seventeen centuries ago so covered up and protected the remains of Herculaneum and Pompeii, that even now the smallest relics of Roman daily life are preserved for our inspection, so may the muddy deposit now taking place over a large extent of the present sea bottom preserve, for the inspection of future generations, the remains of the creatures at present living and dying there.

For the sake of clearness it has been provisionally assumed that, in all these instances, the organic bodies have been preserved by being enveloped in masses of inorganic matter; that the mud which forms the bottom of seas and rivers is, in all cases, pulverized rock brought from other localities. It is very rare, however, to find mud purely of this character, and there are some remarkable accumulations at present taking place, of which every particle is derived from organisms which have once lived, the apparent mud, in which the large organisms are imbedded, being nothing but a mass of shells of minuter forms intermingled with fragments of larger ones.

5. Most important consequences flow from a recognition of the fact that the modes of preservation of the remains of animals and plants last described far outweigh every other in importance and extent. This may be made more clear by again using the instance of Pompeii and Herculaneum as an illustration. Suppose that long after these cities were buried others had been built over them by some of the many barbarian invaders of Italy, during the decline of the empire, and that after a while Vesuvius had entombed these under another shower of ashes; and that these had, after a few hundred years of existence, undergone a like fate, so that the whole of this part of Italy was buried under volcanic accumulations, on the surface of which flourished the villages and vineyards of a race ignorant of the existence of a previous

condition of things. And now suppose a well to be sunk, or an excavation made for some purpose or other, down to the original foundation of Pompeii; the digger would pass through three layers of volcanic accumulations, separating the foundations of as many cities, differing in the style of their architecture, in their sculpture, their paintings, and their utensils, and clearly showing that they belonged to three separate nations. It would be quite clear, again, to the excavator, that the highest city must be the latest and last built, the lowest the earliest; and he could arrive at no other conclusion than that three several races had flourished and perished, one after another, on this very spot in ancient times. For how great a space of time each race had remained, and what was the absolute antiquity of any one, or of the whole, he would be unable to say; but their relative antiquity—the chronology of the series, would be plainly indicated by the order of their superposition.

Exactly the same reasoning is applicable to the beds of mud and sand which are now accumulating and gradually hardening into rock at the bottom of our present seas. Those layers which are at present being deposited, necessarily lie above those which were formed in the same locality a year ago; and these, above those of the preceding year; while, on the other hand, they will be covered up by deposits of future years. Therefore, it follows, that if ever the present sea beds are upheaved, so that their composition may be examined, the future observer will find the beds containing the remains of marine animals and plants superimposed upon one another, in precisely the same order as they are now being formed, the oldest at the bottom, the youngest at the top; he will be furnished by their order of superposition with an accurate *relative* chronology of the changes which are now taking place; but without the introduction of other considerations, he will, of course, be unable to assign the *absolute* period at which any bed was deposited, or the time occupied in the formation of the whole.

The antiquarian called upon to estimate the probable absolute age of the oldest of the cities in the imaginary case stated above, would be guided by what he knew of the time required to build cities; by historical evidence as to the conditions under which nations replace and extirpate one another; and by physical considerations based upon a knowledge of the mode and rate of the formation of volcanic accumulations of a given thickness; but even then, he would, probably, prefer to state the minimum rather than the maximum antiquity. And so the future naturalist, should he have no other light than the strata now forming themselves afford, can only be guided, in his estimate of their antiquity and of the period occupied in their formation, by his knowledge of the average duration of animal life, and of the rate at which sediment of a given thickness can be deposited. He may as well assume the remains before his eyes to be accidental "sports of nature" at once, as speculate upon any other foundation.

Just as our only means of comprehending the civil history of the past is to apply to ancient times those principles which a careful study of the actions and motives of our contemporaries leads us to believe are of universal application to mankind, so, in endeavoring to interpret the monuments of the ancient world of geology, we must be guided by what we know of the present creation; and thus having learned what living creatures now exist, how they are constructed, and how their remains are becoming imbedded in the rocks now forming, we are ready to enter upon the inquiry as to what forms of life animated the ancient worlds, how they were constructed, and how their remains have been handed down from those remote ages.

6. There are yet one or two collateral points which require discussion. Supposing that the present bed of the ocean were upheaved and became exposed to view, so that we could examine the organic contents of all the strata of mud and sand which have accumulated and hardened into stone for the last four or five thousand years, ought we to expect to find, at any one spot, a complete and unbroken series of the remains of all the creatures that have ever lived there? Assuredly not. In the first place, it has already been explained that there are many animals entirely devoid of parts sufficiently hard to be preservable, and of them every trace would have disappeared. It is important to remark that a naturalist who should have become acquainted with the present animal creation only in this way, would be ignorant of the existence of many genera and families, of some orders, and even of one or two entire classes; but no sub-kingdom would be without abundant representatives, and, therefore, he would be perfectly acquainted with all the great types of organization at present existing. There would necessarily be defects in his knowledge, but these defects would by no means interfere with his obtaining a very clear and just, though not complete, idea of the present state of things.

But there are other and more formidable sources of imperfection in our palaeontological knowledge. Not only does the very nature of some animals present an insuperable bar to the preservation of a complete record of organic life in the rocks contemporaneously formed, but it is, to say the least, excessively improbable that a complete series of even those organic bodies which are preservable should be found at any one spot. For modern research teaches that the level of the land is constantly changing; slowly but surely, some countries are rising, while others are becoming depressed; and there is good evidence that, in some parts of the world, several alternative movements of elevation and depression have taken place within a comparatively modern period. Now, whenever the bottom of the sea becomes dry land, or the dry land sinks to the bottom of the sea, there must obviously be an interruption in the series of living inhabitants, aquatic forms replacing terrestrial, or *vice versa*. Thus, should the sea bottom be raised into dry land, and then depressed again so as to be covered with fresh deposits, the whole mass, when subsequently elevated and exposed to view, will exhibit a break in the series of marine organic remains, corresponding in magnitude and importance with the interval during which the sea bed remained in the condition of dry land. It is probable that there is not a single spot on the earth's surface which has not been thus subjected to many alterations of elevation and depression, and, hence, we may safely infer that no single series of superimposed strata can contain a complete series of even those forms of past life which have flourished in that one region.

But, if this be true of those marine animals whose chances of preservation are greatest, whose hard parts contain so little animal matter as to be not worth attack on the part of predacious organisms, which are sufficiently dense to resist the destructive agencies to which they must almost necessarily be exposed before they are protected by sediment, and whose locomotive powers are insufficient to enable them to escape by migration the imminent fate threatened by changes of level, how much more fortuitous must be the preservation of those remains which, like the bones of the marine *Vertebrata*, contain much animal matter, and are comparatively soft, or which belong to entirely terrestrial creatures. And, in fact, it is among the rarest of occurrences to find the bones of a dead wild quadruped, or bird; or to dredge up from the sea bottom a relic of a fish or of a porpoise, abundant as these animals are in our seas.

We turn to the examination of the collection of fossil remains, then, bearing this truth clearly in our minds, that at best it contains only an imperfect record of the past; that it is a history, some of whose leaves are certainly torn out—we know not how many or how few—though, judging by the present condition of things, we surmise that their teachings would not contradict any duly limited deduction from the information we derive from other sources.

III.—Application of Natural History to the Elucidation of Fossils, or "Palaeontology."

1. An important question meets us on the threshold, as it met those who first directed their attention to fossils: How do we know that these curiously-formed bodies, often to all appearance of one substance with the rock in which they are imbedded, really are the remains of creatures which have lived? How do we know that they are not what the ancients supposed them to be, *lusus naturæ*, sports and freaks of inorganic nature, produced in blind imitation of living bodies, just as the hoar frost on the window panes simulates the foliage of a tree?

We know that fossils are the remains of animals and plants by precisely the same common-sense reasoning as that which led Robinson Crusoe, seeing the impression of a human foot on the sand, to conclude that a man had been there. The foot mark might by possibility have been an accident, a *lusus naturæ*, but pending the proof that it was so the precautions of the shipwrecked mariner exhibited the soundness of his judgment. We cannot experimentally prove that fossils are truly the remains of dead animals and plants any more than we can experimentally demonstrate that the utensils recently brought home from the arctic regions really belonged to the crew of the "Erebus" and "Terror;" but all the facts, the condition in which the things were found, the marks upon them, agree with this hypothesis, and none oppose it. On like grounds, our belief that fossils are the remains of beings which once lived has acquired firm hold and remains unshaken; the conditions under which they are found, and all their marks, agree with the hypothesis; while increasing knowledge, so far from shaking, is incessantly, and in very wonderful ways, strengthening the foundations of this as of every truth.

2. The extent to which it enables us to reason to the unknown is commonly, and in a great measure justly, regarded as one of the best tests of the truth or falsehood of a scientific theory, and none has ever more brilliantly stood the application of this test than that now referred to. For if fossils really are the remains of living beings we may reasonably expect, in the absence of evidence to the contrary, that the animals and plants of which they are the exuvia came under the operation of the same great law of the invariable correlation of organic peculiarities, which has been shown above to be manifested in the present creation, and it might be fairly anticipated that the same logical process which enables us to reason from the structure of the hair of a recent animal to its whole frame, or from the peculiarities of the wood of an existing plant to its fruit, and the minor particulars of its embryology would be equally available when applied to the extinct inhabitants of the world.

The magnificent researches of Cuvier first practically demonstrated the justice of these surmises, and showed that the laws of correlation of parts deduced from the observation of living animals hold good to a wonderful extent among the extinct forms; so that to one as thoroughly acquainted as he was with the details of animal organization, an isolated fragment of a fossil bone, or an odd tooth, was, frequently, sufficient to

indicate the general affinities of the animal to which it belonged; and to justify him in making those wonderful predictions of what would be the nature of its other parts, which were so often to be verified in the course of future investigations.

One of the most remarkable examples of such successful prediction is that which Cuvier himself mentions as "a very singular monument of the force of zoological laws, and of the use which may be made of them." From the famous gypsum quarries which furnished so many occasions for the display of his genius and knowledge a block was brought containing the imperfect remains of the skeleton of a small animal; the shape of the lower jaw and the characters of the teeth were such as are alone known to exist in the order of marsupial animals, of which the opossum and the kangaroo are the most familiar examples. But all known *Marsupialia* possess two remarkable appendages to the "pelvis" or bony girdle of the hips, which are termed the "marsupial bones," because they are connected with the pouch in the female. Here was a law of invariable correlation of anatomical peculiarities (certain teeth and certain forms of jaw being always associated with the presence of these bones) of universal application to living animals; would the law hold good for the fossil? Cuvier was so confident that it would, that he invited some friends to witness the picking away of the stone from the region where he believed the marsupial bones would be found, and the result verified his expectation, for the bones were discovered just in that very situation.

3. It will be easily understood, however, that the whole of this train of reasoning is only valid on the assumption that a certain uniformity has prevailed in organic nature; that the structures which we find invariably associated now were invariably associated in earlier times; that, in short, the great laws which are expressed by our conceptions of common plans have always remained the same. We know of no reason, save the invariable occurrence of the co-existence, why a peculiar form of jaw should always be accompanied by the existence of marsupial bones; and just as certain animals now exist in which the marsupial bones are present, while the peculiar structure of jaw is absent, so it is quite within the limits of possibility that, at an earlier period of the earth's history, animals might have existed possessing the peculiar jaw, but deprived of the marsupial bones. Of course, in this case Cuvier's reasoning would not have been conclusive, and his prophecy might not have been verified.

In point of fact it would not be safe in all cases to regard the laws of invariable anatomical correlation, deduced from the observation of the existing animal world, as applicable, without reservation, to the members of extinct faunas. No generalization from the structure of existing animals could be better established than that biconcave vertebræ are found, throughout the spinal column, only in fishes and perennibranchiate amphibia, or hollow bones of a certain form are characteristic of birds, and yet we should be led into most erroneous conclusions by reasoning without hesitation from these data, to the structure and affinities of the animals to which certain vertebræ and certain bird-like bones found in the mesozoic strata belong. In fact, while experience shows, with a constantly increasing weight of proof, that the great laws of the construction of animals have been identical throughout all recorded time, and while, therefore, when we possess any clear indication that a fossil animal belongs to any one of the great groups, we may safely predict that it will exhibit all the other *characteristic* peculiarities of that group; we must be careful to remember that in many of the smaller groups combinations of organic peculiarities have existed of a very different nature

from those which now obtain; and we must, therefore, be content to regard many of the established generalizations as only approximatively correct.

As a general rule, however, it is very true that the more we learn of the world of fossils, the more clearly does the conviction force itself upon our minds, that from the earliest times of which we possess a record to the present, no change has taken place in the general scheme of the organic world. There are perhaps 15,000 established species of extinct animals, but among them there is not one whose plan of construction differs so far from any now known, as to require the establishment of even a new class for its reception. Different naturalists will estimate the number of classes of animals now living variously; but they may be safely assumed to be at least five-and-twenty distinct modifications of the five great primitive common plans; and yet so comparatively slight has been the change since the earliest times, that the whole extinct world will not supply us with a six-and-twentieth modification. If we descend to the next smaller divisions, to the orders, the same fact becomes apparent; at the very lowest estimate there are not fewer than between a hundred and thirty and a hundred and forty orders of animals, and out of these, at the most, not more than fourteen or fifteen are represented only by extinct forms; that is to say, in the whole range of geological series not more than ten or twelve per cent. of ordinal types, different from those which now exist, having come into being.*

4. The history told by the records of the organic world is in perfect harmony with that which is written on the face of inorganic nature. The thickness of the crust of the earth, down to the greatest depths to which man has been enabled to penetrate, is to a great extent composed of strata of rock, the physical and chemical peculiarities of which evince their identity with the products of the present operations of nature. Beds of conglomerate containing round pebbles demonstrate that the sea beat against and broke up its rocky boundaries then as now, rounding and polishing the fragments by incessant friction as it wears them on any modern shingle beach; fine-grained limestones and sandstones show that, then as now, the finer products of their attrition were carried away and deposited, in the form of beds of mud, upon the deeper and quieter parts of the sea bottom. Vast and frequent interruptions in the regular series of bed prove that, in ancient times as at present, the solid crust oscillated, so that what was dry land became covered by the sea, and what was sea bottom remained for long ages dry land. And, finally, in like manner as we know that, within the period of which man is cognizant, all these changes have gone on in an excessively slow and gradual manner, rapid and convulsive action being altogether exceptional, so we have the clearest proof that the time represented by the vast succession of ancient strata is enormous and almost inconceivable, and that gradual and regular change was, then as now, the rule, catastrophe and convulsion the exception. Nevertheless, as in the ancient organic world we have found that there is a certain amount of departure from what might be called the by-laws of the present creation, so it is quite possible that, in the physical world of past times, changes may have now and then taken place with a rapidity and a violence to which the minute experience of man affords no parallel. An *Ichthyosaurus* is, in one sense, a sort of animal catastrophe, and as we are all well assured of the occurrence of this one wide deviation from

* The number of orders is here purposely taken at an extreme minimum; while the highest possible value is given to the extinct groups.

existing manifestations of the vital forces, so we must not be too sure that corresponding departures from the usual order of the physical world have not occurred in past times.

The same analogies which demand this caution, however, fully justify us in concluding that throughout all geological time the great physical forces have obeyed similar laws. The gravitation of matter, its hardness, the effects of heat and of chemical affinity upon it, have been the same, we have every reason to believe, from the Cambrian age to the present, and, as a consequence, it cannot be doubted that the vital actions of the trilobites were governed by the same physiological laws as those by which we now live and move and have our being. For, leaving the phenomena of consciousness out of the question, physiology is but an application of physics and chemistry.

5. Now, just as the restorations of the palaeontologist imply his confidence in the uniformity of the great laws of morphology throughout all time, so the chronology of geology, the basis of the whole science, rests upon a like assumption with regard to the general uniformity of the laws of physics and chemistry. It would be ridiculous to argue from the superposition of ancient beds, unless we assumed that their constituent particles gravitated in the same way then as now; the identity of mineral character of two beds could prove nothing, without the assumption that the laws governing chemical changes have always been the same; and, in like manner, we can reason on the general habits of ancient living beings only on the assumption that the great laws of physiology were the same then as now. No half measures will avail; we must be prepared either to assume the general uniformity of ancient and modern action, or we must give up the problem, for no other hypothesis affords the least criterion of truth, or the slightest check upon the play of the imagination. But if we may argue from like effects to like causes, then geological chronology is as much a matter of science, and capable of being tested as thoroughly, as any other case of succession.

The arguments on which these chronological considerations are founded are simple and intelligible enough. It has been already proved that, in the present state of things, the lowest of any series of beds which have been deposited from water is of necessity the oldest. If, then, the great majority of the ancient strata have also been deposited from water, if they are nothing but the hardened muddy beds of ancient seas and lakes, (a fact of which there is abundant evidence,) then the same law necessarily applies to them—the lowest stratum is the oldest, and the superjacent beds have all been deposited during a subsequent period. The argument applies with equal force to the whole crust of the earth, and if we could tell how much time was required for the formation of each bed, we should, by adding all the periods together, arrive at the smallest possible interval which can have elapsed since the deposition of the oldest bed. We have no data sufficient to enable us to say, with any approximation to accuracy, how long it takes to deposit sufficient mud or sand to form, when hardened, a layer of rock two feet thick; but we are quite safe in saying that neither lake nor sea ever deposited that amount upon its bed in the course of a year.* Now the total measured thickness of ancient strata, deposited either from fresh or salt water, is not less than 60,000 feet, (or about twelve miles,) so that,

* Exceptional deposits, as, for instance, by earthquake floods, are here left out of consideration, as they can have had but little influence on the sum total of the aqueous formations. The total thickness of the latter here assumed is midway between the estimates of Professor Phillips and Sir C. Lyell.

even assuming them to have been deposited, without interruption, at a rate faster than any sea or lake deposits mud now-a-days, we should still require a period six times as long as that of which any human record exists, for their formation. But, in truth, when we take into account the probably immensely greater time required for the formation of two feet of sedimentary deposit, the vast amount of rock which has been formed and subsequently swept away by denudation, so that it is not reckoned in estimating this total thickness of the strata, and the possibility that masses of strata, which will require interpolation in the general series, lie hidden from our view in parts of the world which have not yet been examined, or under the present bed of the sea, the most sober calculator will hardly venture to limit the factor by which even a period of thirty thousand years should be multiplied to give the whole period recorded by the monuments of geology.

The conclusions here drawn from the facts of physical geology are in perfect unison with the chronological indications afforded by fossils. Beds many feet in thickness, composed of the remains of marine animals, their shells unbroken and undisturbed, and sometimes covered with parasitic growths, (just like recent dead shells which remain long undisturbed at the bottom of the ocean,) are constantly met with. Here and there are thick strata, composed of nothing but the remains of microscopic plants and animals, which must have required a vast time for their aggregation; elsewhere, the vestiges of huge coral reefs testify that innumerable generations of their slowly-growing fabricators must have lived and died undisturbed, in one locality; and, in some places, enormous accumulations of the bones of large vertebrata, each individual of which must have required many years to attain its full growth, tell the same tale.

The two great astronomical truths to which the general mind has always found the greatest difficulty in assenting are, first, the doctrine that the seemingly fixed earth moves, while the apparently moving sun stands still; secondly, that the earth is but a particle, and the diameter of the system to which it belongs insignificant when compared with the vast space which separates one of the greater heavenly bodies from another. Geology presents two corresponding truths, as hard to believe and yet as well founded. The first is, that the seemingly fixed land is subject to incessant oscillations, while the sea, so mobile on the small scale, remains in reality comparatively unchanged. The other is, that our historical period, even if we include the widest limit to which tradition would carry the records of our race, is but an insignificant portion of the countless ages which have elapsed since the animals, the remains of which are exposed to view in the Lower Silurian cases of this collection, lived and died, and were buried in the oozy bed of the ocean of that period.

We are, therefore, compelled to believe that a general uniformity has prevailed in the operations of physical and vital nature throughout all time of which we haveany record; but just as the generally uniform and regular movement of the celestial bodies is quite consistent with minor and subordinate perturbations, so the proved uniformity of action of the causes in operation in the physical world by no means excludes the possibility of occasional sudden and immense changes, or "catastrophes," as they have been called; nor does the equally evident general uniformity of plan predominant throughout the ancient fauna and flora in any way interfere with very great and important deviations from those which now exist.

REMARKS ON THE "CARA GIGANTESCA" OF YZAMAL IN YUCATAN.

By Dr. Arthur Schott.

Of the many remarkable relics of ancient Maya civilization, the little town of Yzamal, situated about thirty miles east of Mérida, has a considerable share. One of the most valuable, because mythographically most eloquent, is the so-called "*Cara Gigantesca*," (gigantic face,) a colossal work in stucco on the east side of a solidly built stone dam, running north and south between various sacred mounds, or "kues," as the Mayas call them, and of which the historians of the Spanish conquests mention ten or eleven as in existence almost intact, shortly after the subjugation of the peninsula.

Stephens, in his "*Incidents of Travel in Yucatan*," also speaks of the curious face on the wall, which he had visited in the courtyard of Señora Mendez. This author, however, devoted only a few cursory remarks, together with an equally unsatisfactory illustration, to a subject which well deserves the close attention of the antiquarian.

There is nothing in the features of the image which should be designated as *stern* and *harsh*, as Mr. Stephens has done, for the only strange feeling this face may produce is caused by the colossal scale in which the whole work is projected. Otherwise the face, with its oblong, oval outline, exhibits what the Spanish define as a "*cara angosta*," (narrow face,) in opposition to the broad, square type of the common Indian of the land. The features are rather feminine, which is only a generally recognized peculiarity of the American aborigines. The whole face exhibits a very remarkable regularity and conforms strictly to the universally accepted principles of beauty, which have been handed down to the art of the present day by the masters of ancient Greece. A vertical line drawn over the forehead, nose, and chin, divides itself naturally into three equal parts, each of which corresponds exactly to the frontal, nasal, and maxillary regions. The opened mouth, bringing the upper teeth almost into full view, together with the rounded nostrils and the slightly elevated tip of the nose, impart to the whole a singular expression, which is certainly not accidental, but agrees strictly with the supposed purpose for which this face was made, and which will be more manifest by the following remarks.

The outline of the face or head varies from the Greek oval by approaching nearer to a rounded oblong, for the cheek and jawbones are rather more developed than the rules of classic beauty would admit. The head-dress in the shape of a mitre is encircled just above the forehead by a band, which is fastened in front by a triple locket or tassel. A singular deviation from nature is exhibited by the ears, which are made to project forward. Under the chin three flat stone plates project, while the space on both sides of the head is filled up with numerous arabesque curves of various kinds. The whole of this remarkable piece of stucco work occupies a space of about ten feet square.

There is little doubt but that this work in its time must have served as a sort of altar, upon which the offerings of burnt incense were de-

posited accompanied by the prayers of the devotees. Mr. Stephens also held this opinion not only on the strength of certain popular traditions, but by virtue of some direct historical accounts of the Mayas. The blackened and charred marks on the three stone plates below seem to corroborate this assertion. Whether the image was once intended to represent a deity or demi-god cannot now be proved to a certainty, but its nature can reasonably be guessed at, so that it may properly be taken as a representation of Ytzamatul himself, who was the semi-divine founder and legislator of the ancient realm of Ytzmal, now Yzamal. In order to enable the reader to judge for himself, an extract from the early history of the Maya confederation in Yucatan may be acceptable.

After the fall of the first Maya empire during the eighth century of our era, when Chichen Itza, the then center of civilization, lost her prestige as the principal city, Ytzmal became the foremost place in the country. Here ruled Ytzamatul, the son of the true, living God, as he was believed to have been. None ever knew whence he had come, for whenever asked as to his origin he invariably answered: "*Ytzen caan, Ytzen muyal*," which means, "*I am the dew of heaven, the substance of the clouds.*" It is, perhaps, also not improbable that this king's name was more a title than a real name, for in the Maya idiom it embodies a whole sentence within a single word, the meaning of which is, "*He who receives and possesses the grace.*" Be this as it may, this name makes it obvious that its royal bearer must have been considered by his people as a semi-divine mediator between heaven and earth, an idea by no means novel in the history of human civilization. The real existence of such a personage is, in a strictly historical sense, of little importance, but is noteworthy for the ethnographer, that the traditional divine or semi-divine nature of the rulers and founders of empires is such a constant occurrence in semi-historical ages, as to be invariably found in some form at the commencement of the history of every nation.

Ytzamatul, with his superior nature, according to Maya traditions, did not fail to enjoy the unbounded love and equally profound respect of the nation over whose destinies he presided. His wisdom as a statesman and legislator, as well as his never failing justice as dispenser of the laws, gained for him so much the admiration of every one of his subjects, that after his death the honor of an apotheosis was accorded to him; and in order to do full justice to his memory, and to give tangible proof of the general veneration for the departed chief, his royal body was divided into various portions, over each of which a sepulchral temple was erected. These sanctuaries soon became converted into so many places of worship, where the pious could offer their prayers and supplications. The names of some of these temples, each crowning at that time an artificial mound called "kues," have been preserved by several of the Spanish historians. Among them one appears which was called "*Kinich Kakmo*," that is, "*Sun with the face*;" another, "*Kabul*," which means, "*The working (creating) hand.*"

Tradition has it that in both these temples sacred fires and sepulchral lamps were burning day and night. Oracles were also pronounced there, and the faithful brought thither their sick and dead, which in many instances became restored to health and life again by the miraculous intercession of Ytzamatul's sacred memory. These places were said to have become thus famous and renowned, not only throughout the whole of the peninsula, but also far beyond its limits, whence a continuous pilgrimage was kept up. Hundreds and thousands joined in pious processions from Cuba, Hayti, and Jamaica, as well as from the interior of Guatemala, Tabasco, and Chiapas. In order to facilitate such religious

national intercourse, terraced and paved highways were constructed leading out from Yzamal toward the four cardinal points. Of these colossal structures, many remnants can still be seen in various parts of the country, while other portions of them are lying hidden in the almost impenetrable woods and wilds, covering at present the main part of the surface of the country. In the very vicinity of Yzamal a considerable piece of such an ancient road can be examined within the limits of a village called "Ɔiticum,"* (pronounced Tziticum,) distant two Spanish leagues west of Yzamal.

Among the details of our present relic, the head-dress, a mitre in form of an obtuse cone, with its symbolic adornments, at once indicates the sublime dignity of a sovereign, or, at least, of the supreme dispenser of the nation's laws. The cincture encircling it, together with its triple locket or tassel in front, is the emblem of universal power and divine perfection, such as was always and invariably attributed to a sovereign before monarchism had passed its zenith of popular belief. According to the ideas of the ancient nations of this continent, as well as of those of the eastern hemisphere, a single band around the forehead was the badge of a nation's ruler. The mighty kings of ancient Persia, for instance, wore nothing else, and it was only in after times that from such a simple adornment the golden ring, the diadem, or crown, originated. Among the numerals the sacred three has ever been considered the mark of perfection, and was therefore exclusively ascribed to the Supreme Deity, or to its earthly representive—a king, emperor, or any sovereign, who, allegorically, stood between God and the nation, and was generally believed to be a descendant of the former. For this reason triple emblems of various shapes and applications are found on sundry objects of royal adornment, but especially on such as belts, neckties, or any encircling fixture, as can be most frequently observed on the works of ancient art in Yucatan, Guatemala, Chiapas, Mexico, &c., whenever the object has reference to divine supremacy.

Behind and on both sides from under the mitre, a short veil falls upon the shoulders so as to protect the back of the head and the neck. This particular appendage vividly calls to mind the same feature in the symbolic adornments of Egyptian or Hindoo priests, and even those of the Hebrew hierarchy. Among the many fragments of ancient sculpture and architecture strewing the extensive area of Mayapan, at one time the metropolis of Maya empire, several heads of the same appearance, and adorned in the same way, occur, though varying a little in some unessential particulars. The same is the case with sculptured heads found at the celebrated Uxmal, (pronounced Ushmal.) A mitre, in shape exactly like those here referred to, also marks one of the resting stations of the Aztec migration, as can be seen on the *Historic-Hieroglyphic Table*, which, as a valuable relic of that interesting nation, is preserved in the national museum in the city of Mexico.

Apparently more difficult to understand in our Yzamal work of art seems to be what is fixed in place of the ears, together with the adornments filling up the space on both sides of the head. To decipher these enigmatic delineations, we have, besides the direct explanations of the older commentators of Mexican history, and especially those of Clavigero, the general character of similar mythographical representations of other ancient and modern nations of this continent as well as those of Asia, which all exhibit the strictest similarity if not congruency, even in detail, if idiographically compared.

* The inverted C (Ɔ) is adopted by the Spanish in the Maya grammar to represent the sound of *tz*, and can so be conveniently employed.—THE AUTHOR.

Among the ancients of Mexico and Peru it was considered a principal requisite for a sovereign, or even a lord of lesser powers, that he should never fail at any time to first receive the high commands of Heaven, which with all theocratic nations formed the base of all secular law and justice. It was likewise indispensable for him to listen impartially to the supplications of those whose destinies Providence had placed in his hands. Without the most scrupulous observance of such sacred duties no monarch or lord could rightfully and for any length of time enjoy the high prerogatives of his exalted station. The history of the Toltecs and Aztecs, like that of the Mayas in Yucatan, records several examples of reckless monarchs and transgressing rulers, against whom an indignant nation rose up in the defense of the outraged laws. Such revolutionary movements terminated, almost without an exception, in the loss of crown and life by the accused, and in most cases with an entire breaking up of the empire itself. The Toltecs on such an occasion lost their whole prestige in the valley of Mexico. The Mayas, their immediate descendants in Yucatan, repeated the same twice. Here the first enactment of popular wrath ended with the destruction of the realm of Chichen Itza, the oldest in that peninsula. The licentiousness and profligacy of two brothers ruling at the same time, under a sort of duumvirate, was the cause of the uprising of the nations which cost the two princes their lives and the supremacy of that realm. In a similar way the kingdom of Mayapan, the then center of Maya glory under the dynasty of the "Cocomes," came to its end by a twenty years' war, the cause of which was the most insulting neglect of the nation's laws on the part of the rulers of Mayapan, while all the other confederate powers, and especially those of the kingdom of Uxmal had risen to satisfy the offended people. The destruction of Mayapan, a large fortified city of nearly three Spanish leagues in circumference, took place about a hundred years before the first Spanish invasion of Yucatan.

Deaf to the sacred word of the law and deaf to the prayers of the suffering subjects, these supreme lords of the nation, forgetful of their obligations, forfeited crown and life, and their defections, like an untied knot, necessarily weakened the very foundation of the whole political structure. It is, therefore, but natural if the contemplative mind of those ancient nations, in their ever apparent symbolism, laid such stress upon the hearing organ of their rulers.

The ideological view of this particular, confessedly so taken by the Peruvian, Mexican, and Maya, may also explain the singular customs among the former, where the Incas and the high nobility used to artificially enlarge their ears by wearing in them from early boyhood heavy gold rings and other trinkets. The extraordinary size of the external hearing organs, by themselves so much appreciated as a mark of high distinction, did not fail to bring them into ridicule with the Spanish conquerors, who nicknamed them "*Orejones*"—that is, "Big ears."

Whether or not the Mayas ever extended symbolism to such a degree as to subject parts of the living body to a similar official disfiguring is not known; but a hyperbolic shaping of the ears or other members of the body on the persons of high distinction can be frequently observed throughout the representations of their graphic arts, and our present relic furnishes an unmistakable example of it.

Here two orbicular plates with perforated center take the place of the ears. Four knobs in high-relief, probably with reference to the four cardinal points, divide these rings, or perhaps wheels, into so many equal quadrants. Rings and wheels signify among the glyphics of the Aztecs and Toltecs, and consequently also of the Mayas, the space of

one year, as can be seen everywhere on their calendar or monumental slabs. If made tetramerous, as are the present ones, they may have particular reference to their quadriennial cycle, called by them *Katun*, and may serve here as a symbol of space and time combined. The exact connection of thought between sign and the ear of a ruler can only be suggested.

Leaving theorizing to the reader, it may be well to call attention to similar ideographies which were used in ancient Asia and Europe. The Greek, for instance, attributed to Saturnus and Kronos a wheel as a symbol. The name of the latter as well as his attributes clearly have reference to time. Both Kronos and Saturnus are, again, identical with Krodo and Satar, of the heathenish Saxons, who combined with these personifications the same ideas as did the Greeks, who received the elements of their theogony from that of older Asiatic nations. Krodo, like Kronos, was represented with a wheel. The Greek also associated Saturnus, as the judging ruler in the realm of death, with Nemesis, Adrastea, as his consort. Various representations of the ancient Orient show both these personifications—that is, Saturnus holding the scale of Nemesis, and she having his wheel at her feet.

Though a direct idiosyncratic correlation between Asiatic and American symbolism cannot be proved here, the example may at least be accepted as one of those numberless instances which comparative ethnography should never overlook.

The two loopknots affixed, one above the right and the other below the left ear, are again the symbols of pledge or obligation, and may here indicate the bearer's duty to receive the grace from above and listen to the prayers of the afflicted below.

The diversely-shaped curves filling up the space to both sides of the head represent, according to Clavigero's direct statements made elsewhere, the prayers and invocations of the devoted. They curl up like smoke and incense while seeking entrance to the ears of the paternal monarch, such as history and tradition represent Ytzamatul to have been.

In the earliest records of the Maya nation, in regard to the realm of Yzamal, no other ruler of such a sublime nature is mentioned, though it seems that in various epochs other sections of this widely-extended theocratic confederacy severally claim such primordial legislators, more or less modified in name and form, but all said to have been gods or demigods. Thus, Chichen Itza had her Zamná, Mayapan her Cuculcan, which latter seems to have been of still higher rank, and is, in form and nature, the Maya equivalent for the Mexican Quetzalcoatl.

The mythical halo surrounding the historical record of Ytzamatul seems to have so much overshadowed the memory of his successors in office that it would be rather hazardous to connect the image on the wall with any other personage but with that first ruler and legislator of Yzamal, or, better, Ytzmal, as it was called before this name was hispanized by the European conquerors.

There can be but little risk in referring the "*Cara gigantesca*" in its colossal size to a representation of the one who, according to his people's belief, "*Receives and possesses the grace*," as the name of Ytzamatul is said to signify.

FORESTS AND THEIR CLIMATIC INFLUENCE.

By M. Becquerel, *Member of the French Institute.*

[Translated for the Smithsonian Institution.*]

FORESTS CONSIDERED IN A CLIMATOLOGICAL POINT OF VIEW.

Forests exercise several kinds of influence over climate; but, to appreciate them properly, it is necessary to define what we understand by *climate.*

The climate of a country, according to Humboldt, is the union of the phenomena, whether calorific, aqueous, luminous, aerial, electrical, &c., which impress on that country a definite meteorological character, different from that of another country situated under the same latitude and placed in the same geological conditions. Accordingly as one of these phenomena predominates, the climate is said to be warm, cold, or temperate, dry or humid, calm or variable. Heat, however, is regarded as exerting the greatest influence; after this follow the quantities of water which fall in different seasons of the year, the humidity or dryness of the air, the prevailing winds, the number and distribution of storms in the course of the year; the serenity or nebulosity of the air; the nature of the soil and that of the vegetation which covers it, accordingly as this is spontaneous or the result of culture.

1. What is the part which forests fulfill as a shelter against the winds or in retarding the evaporation of the rain-water? 2. What is the influence of trees on the water imbibed by the roots and on that which exudes by the leaves, as modifying the hygrometric state of the ambient air? 3. How do they modify the calorific state of a country? 4. Do forests exert an influence on the quantity of water which falls, and on the distribution of rains in the course of the year, as well as on the system of running waters and those of springs? 5. How do they intervene for the preservation of mountains and of slopes? 6. Do forests serve to withdraw from storm-clouds their electricity, and thus to moderate their effect on neighboring and unwooded regions? 7. What is the nature of the influence which they are capable of exerting as regards the public health?

From this series of questions it will be seen how much caution is to be observed before we pronounce on the influence which the *disboscation* or clearing away of the forests of a country may exert on its climate. It is necessary, first, to know the geographical position, the geological constitution of that country, its latitude, its proximity to or remoteness from the sea, the nature of its soil and that of its subsoil, according as one or the other is permeable or impermeable, siliceous, calcareous, or argillaceous—elements which must all be taken into consideration. These questions, with the exception of a few, not being susceptible of solution *a priori*, exact, of course, a special examination and experimental study, without which we incur the risk of pronouncing an opinion not in accordance with that of one who may have considered the

* From the *Atlas Météorologique de l'Observatoire Impérial.* Folio, Paris, 1867.

subject from a different point of view, or embraced but a part of the question. Let us adduce the proofs:

The action of forests on the climate of a country is very complex, for it further depends, first, on their extent, their elevation, the nature of the soil, and of the subsoil; second, on their *orientation* or direction with regard to the winds, whether warm or cold, dry or humid; third, on the age at which they are cut, on their species, that is to say, whether the leaves be caducous or persistent, seeing that the radiating and exhalant.properties are not the same at all seasons; fourth, on the season of rain, whether in summer, autumn, or winter; fifth, on the proximity of pestilential marshes, &c.

Whatever be the action exerted by a forest, it will of course bear a relation to its extent, for a tree or group of trees does not act like a large mass; a single tree indicates, by the shade which it throws on the surrounding soil, that its presence is injurious to the culture of plants to a distance which depends on its height; the loftier the forests, the greater the extent of the shade; the shade depends only on the skirt of the forest, and to a certain degree on the density of that skirt.

The height of the trees, if the forest has a certain density, may be an obstacle to the wind, according to their position in regard to the direction of the latter. It is well understood that forests principally act as a shelter only in relation to the lower winds; the obliquity of these is to be taken into consideration, as will be seen hereafter; the depth of the forest supplies to a certain extent the compactness in which it may be deficient. This action will be developed further on. The nature of the soil claims consideration according to the proportions of clay, lime, and silex which enter into its composition. In the case of different combinations of these constituents the effects are quite different, much depending also on the circumstance whether the subsoil be pervious or impervious. All soils, as is well known, may be reduced to the four following divisions:

Pervious soil	1. Pervious subsoil; 2. Impervious subsoil.
Impervious soil	3. Pervious subsoil; 4. Impervious subsoil.

The roots of trees, by penetrating into the soil and subsoil, separate the particles and thus facilitate the escape of the surface waters; the older the trees and the more ancient the preserves, the more deeply do their roots penetrate, and the greater the facility consequently with which the waters traverse the subsoil.

Let us examine the effects of the four kinds of soil above enumerated on the vegetation of forest trees. *First case.* With a pervious soil and pervious subsoil the waters never stagnate, be the soil wooded or not. *Second case.* With a pervious soil and impervious subsoil, stagnation of the waters takes place when the soil is not wooded—of this Brenne and Sologne are examples; if it be wooded and the subsoil have not too great a depth, the waters readily percolate by help of the roots which traverse it; in the contrary case they remain stagnant. *Third case.* The soil impervious, the subsoil pervious: this soil suits only certain species other than the oak. *Fourth case.* Soil and subsoil impervious: with this soil forest culture agrees least of all; yet are there certain species which can live and develop themselves therein. The roots of trees, therefore, by making their way into the soil, fulfill an important part in the distribution of the waters of a country. MM. Gras and Alphonse Surel, from numerous observations made in the higher Alps, explain as follows the effect produced by forests situated on the sides of mountains.

When a sloping surface is overrun by vegetation, first by low plants, then by trees, the roots entwine with one another and form a net-work, which gives consistency to the soil; while the branches, furnished with their leaves, protect it from the violence of rain-storms. The trunks, with the offshoots and brush-wood which surround them, multiply points of resistance to the currents which would otherwise furrow the earth. The effect of vegetation, therefore, is to give more solidity to the soil, and to distribute the waters over the whole surface. The soil, being divided by the roots and covered with a spongy humus, absorbs a part of the waters which cease to flow over the declivities. It is thus that the woods act as a shelter against the force of rains in mountainous countries.

The action of forests as a shelter in regard to winds is not absolute; for the effects depend on the height to which the wind blows. If this height does not attain that of the forest, the wind is arrested at every moment by the trees; loses its velocity; and, if the forest has a sufficient density, will have wholly ceased by the time it reaches its limit. When it blows to a height greater than that of the trees of the forest, the latter has no action except on the lower stratum of the current of air, unless its direction be inclined; above the forest, the upper mass of air which has encountered no obstacle, and which has a horizontal direction, continues with the same velocity. The action, then, of a forest as a shelter, is limited.

Forests may act in still two other ways: when they happen to lie in the direction of a violent current of air, at a maximum of saturation with vapor, a part penetrates into the mass, the other part is dispersed in all directions by the obstacle presented to its passage; the portion which rises, if it encounters a colder stratum of air, yields its vapor to precipitation, and a fall of rain ensues. Again, when a current of humid air charged with pestilential miasms penetrates into a forest of a certain extent, it is altogether divested of them. It has been observed in the Pontine marshes that the interposition of a screen of trees preserves all that is behind it, while uncovered tracts are exposed to fevers. The trees, therefore, sift the infected air by removing its miasms. This fact has been reported by M. Rigaud de Lille, in his work on *malaria*.

M. Hardy, director of the government nurseries at Algiers, has announced facts which clearly show the influence that trees may exercise as a shelter. There exist in Algiers three groups of frutescent or shrubby plants; the first being formed of trees with caducous leaves, poplars, alders, &c., which grow in ravines and on the banks of streams; the second comprising the agave, the cactus, the palms, &c.; the third consisting of vegetable species with persistent leaves, such as the olive, the carob, the wild laurel, &c. M. Hardy has remarked that the trees of the first group which are indigenous grow rather in breadth than in height, and that they constantly present a large and flattened top; if some species happen to attain considerable altitude under the most favorable conditions for their development, they are observed to grow with vigor for some time, but arrived at the height of the trees of the country, the top becomes dry and the branches then extend themselves horizontally. Effects of this kind are to be seen in the poplars planted at Bouffarich, in the center of the plain of Mitidja, under conditions of humidity of soil which leave nothing to be desired for this species, and yet these trees are incapable of surpassing the height of from 10 to 12 metres, (33 to 39 feet.) There are found, it is true, specimens which rise higher and still seem not to suffer at the top, but these are situated at the base of a steep hill whose crest is much more lofty than the trees.

This inability of the vegetation to rise beyond a certain height, which is far from being that at which the tops of such trees ordinarily stop, evidently proves that there exists, at a greater or less elevation, a stratum of air in which development in height is impossible. This effect must be attributed to the air current of the desert, which is warm and dry; all trees which grow in Algeria are subject to its influence. The trees of the third group, the cypresses, the cedars, &c., which brave this influence, rise to a very considerable height.

The principles above set forth suffice to show the part which forests may play as a shelter, and within what limits they act. We are naturally led to examine the value of the contradictory opinions respecting the effects of their removal, enunciated by Arago and Gay-Lussac, in the commission appointed in 1836 to consider the expediency of adopting article 219 of the forest code. "If the screen of forests on the maritime border of Normandy or Brittany," said M. Arago, "were levelled, these countries would become accessible to the west winds, the temperate winds coming from the sea. Hence there would be a diminution in the cold of the winters. If a similar forest were cleared away on the eastern frontier of France, the glacial wind of the east would there be more powerfully propagated, and the winters would be more rigorous: the destruction of a screen of this sort in the one and the other situation would, therefore, have produced effects diametrically opposite."

In principle M. Arago was right, but not absolutely, for the effects depend on the locality where the forests are situated, on their altitude, and on various other causes.

M. Gay-Lussac used very different language: "In my opinion," he said, "no positive proof has thus far been obtained that woods have of themselves any real influence on the climate of a large country or of a particular locality, and especially that they have a different influence from that of all kinds of vegetation. It might be asked if the evaporation of water is the same on a naked soil and one covered with vegetation. The questions are so complicated when considered under a climatic point of view, that the solution is very difficult, not to say impossible. Another advantage in wooded soils which I do not dispute, is to promote the abundance of springs of water. And all, in fact, that tends to arrest the flow of rain-water and to enable it to infiltrate slowly into the earth, instead of passing off in torrents, is favorable to such springs. But once more, this advantage attributed to woods is possessed, in perhaps the highest degree, by a herbaceous vegetation; the close and numerous blades, the comose and interlaced roots, compose a thick and spongy mass which admirably intercepts the movement of the water, retains it, and yields it up by little and little."

On the other hand, M. Beugnot, reporter for the commission named in 1851 to revise, as far as was needful, the forest code in matters relating to clearings, denied, though with less authoritativeness than MM. Gay-Lussac and Arago, the influence exercised by great masses of wood on the climate of a country. In his report he remarks: "The departments of La Loire-Inférieure, La Manche, Le Pas de Calais, Le Nord, La Somme, Le Maine-et-Loire, are among those which are least wooded. Is the climate less salubrious than that of the Landes, of the Gironde, of Loiret, of Cher, and Loiret-Cher, which are among the most densely wooded?" "We arrive," he adds, "at the same conclusion, on comparing together the different countries of Europe; consequently the clearing away of woods is in nowise injurious to the salubrity of the country."

Less proof it would be impossible to bring to the solution of a question. We shall proceed to discuss each of these opinions; not contenting ourselves, like their authors, with adhering to generalities, but by a resort to facts and experiments, the sole means of arriving at a solution.

M. Arago was right in saying that forests served as a shelter against winds, but he did not say within what limits, and yet therein, as we shall show, lies the whole question. The Alps, by reason of their situation and height, protect certain parts of the coast of the Mediterranean, especially those about Nice and Hyères, from the cold winds of the north. The same chain of mountains renders exceptional also the climate of Lake Maggiore, Lake Como, and the neighboring districts. Nothing like this would occur, at least over so great an extent, if, in place of the Alps, which are several thousand metres in height, there were mountains of an ordinary altitude or mere hills; for, the protected surface, as will be seen, depends on the elevation of the mountains. Now, the action of forests, composed of the loftiest trees, having at most a height of from 30 to 40 metres, (100 to 130 feet,) cannot be different from that of simple hills. Their mass supplies in this case the compactness in which they are defective.

"In the plains of Orange," says M. Gasparin, (*Traité d'Agriculture*, t. 1, p. 196,) "the north wind which passes over the mountains of Dauphiné strikes the earth at an angle of about 15°; whence it follows that a height of 200 metres (656 feet) protects a space of 2,160 metres (7,087 feet,) a border always reserved for the most valuable crops, and such as most shun the cold. Under the influence of such a shelter, the mean temperature of the year is raised by more than 1°; whence it is that the orange tree flourishes in the open grounds at Ollioules and Hyères, while it cannot stand the winters of Marseilles; hence, too, the temperature of the air at the Lakes Como and Garda permits the cultivation of the olive, which dares not show itself in the plains of Lombardy."

We will cite still another example which furnishes an idea of the extent which may be protected by a shelter of slight elevation. In the valley of the Rhone, where the *mistral* frequently blows, a simple hedge 2 metres in height (7 feet) is capable of protecting a space of 22 metres (72 feet) in breadth, a limit which, as M. Gasparin observes, should serve as a guide in the discussion. It is by means of such shelters, which are greatly multiplied in this valley, that the cultivation of leguminous plants is possible, as it could not be without this expedient. In the open plains of Provence, hedges of still greater height are obtained by planting the cypress and the laurel. All these shelters, though of little elevation, protect large spaces when the lower currents of cold wind are horizontal. In this connection, we should not forget to mention the different aspect presented by the two faces of the Pyrenees; the tract on the side of Spain, which is exposed to the winds of the south, is arid, while that which looks toward France is covered with pastures of fine vegetation.

The examples which we have just cited suffice to show that the action of forests, even when composed of trees of the tallest growth, is limited and cannot consequently extend to an entire country, as is maintained by M. Arago.

M. Gay-Lussac is still less explicit, for he only propounds questions, or gives their solution *a priori* without proofs in support of it. He asks, for example, whether the evaporation of water is the same on a naked soil as on one covered with vegetation; he asserts, on the other hand, that the influence attributed to trees upon the system of waters pertains in the highest degree to the herbaceous vegetation. The examin-

ation of these questions requires that we should take into consideration the following data:

Schubler has proved that all earths do not possess the same property of imbibition. In 100 parts of earth desiccated to 40° or 50°, the numbers found, for the quantities of water absorbed, are these:

Siliceous sand	25	Pure clay	70
Calcareous sand	29	Fine calcareous earth	85
Barren clay	40	Humus	190

Calcareous and siliceous sands are the substances, therefore, which have least affinity for water, while humus is that which has most. The state of division, as will be seen, has an influence on the conditions of fine calcareous earth. It is impossible to separate, in the present case, the property of imbibition from that of aptitude for desiccation, to which regard must be had in evaporation. Experiment proves that 100 parts of the water of saturated earth lose in four hours, at 13°.75 (57° F.) of temperature:

Siliceous sand	88.0	Argillaceous earth	34.9
Calcareous sand	75.9	Pure clay	31.9
Barren clay	52.0	Lime in fine powder	28.6
Fertile clay	45.7	Humus	20.15

It will be seen from this that siliceous sand is the substance which allows water to escape most easily, while humus is that which retains it longest. Calcareous sand loses water less easily than silicious sand.

We will further mention the results obtained by Melloni in experiments relating to the refrigeration undergone by certain substances under the influence of nocturnal radiation, and which should be taken into consideration:

Substances.	Ratio in the effects of refrigeration.
Plants with smooth leaves	103
Siliceous sand	103
Vegetable earth	92

Now, the absorbing power being equal to the emissive power, it must be admitted that the substances will in the same time acquire heat in the same ratio. Such are the elements which enter into the solution of the question, or rather questions, proposed by M. Gay-Lussac.

When rain falls on the soil, the upper strata first become saturated, then the excess of water passes to the lower stratum, which likewise becomes saturated until the excess of one stratum completely saturates that which is beneath it. When the upper stratum becomes dry through evaporation in the air, it resumes, from that which is below, what it has lost, as does the latter from the third stratum, until all the water primarily absorbed is dissipated. As to the evaporation, it is evidently less, all else being equal, on a wooded surface than on a merely sodded one.

M. Gasparin (*Traité d'Agriculture*, t. II, p. 116) has made experiments on the subject we are considering, and finds, on comparing the evaporation of a surface of water with that of a surface of earth completely saturated, in the month of August, and at a temperature of 23° to 26°, (73° to 79° F.,) the following results as the ratios of one to the other.

	Evaporation from the water.	Evaporation from the earth.
	Millimetres.	*Millimetres.*
First day	15.0	4.1
Second day	13.7	2.5
Third day	11.5	1.8
Fourth day	12.0	1.3
Fifth day	11.7	1.3
Sixth day	11.0	1.2
Seventh day	9.4	1.3

Evaporation, therefore, proceeds rapidly in the earth at first, but, as we see, becomes finally very feeble.

The series of experiments we have above reported show that evaporation must vary considerably with the nature and physical state of the soil, a consideration to which no regard has heretofore been paid; thus, lands covered with low vegetation, or with woods, and whose soil is composed of humus mixed with sand, lime, or clay, absorb more water than those which do not contain humus, and retain it consequently longer than the latter. The effects vary according to the proportions of the different elements which compose the soil. The infiltrations are greater in wooded lands than in sodded, the roots dividing them to a greater depth, and thus facilitating the passage of the waters which are not arrested except by some impervious stratum. The branches of trees provided with leaves not only form an obstacle to the evaporation of the water resting on the surface, but the leaves are further constantly surrounded by an atmosphere of vapor proceeding from exhalation, and which prevents evaporation, in so far as this exhaled water suffices for the saturation of the air; during all this time the infiltration continues in the earth. Herbaceous plants, being deficient in mass, do not produce the same effect; in fact, whoever has been in places wooded in part, and in part covered with sod, must have remarked that, after rain and exposure for some time to the sun, the sodded spaces had become dry, while the wooded were still damp.

Let us speak now of the water taken up by the roots, and of that which is exhaled in the air. The roots of trees, as is proved by the experiments of Hales, Dutrochet, Mirbel, and M. Chevreul, draw in a great quantity of water charged with the divers elements which go to constitute the sap; the surplus of the water is exuded by the leaves, and continually maintains in the ambient medium a humid atmosphere. The water imbibed proceeds not only from the superficial strata, but, moreover, from the more or less deep strata into which the roots penetrate, and which furnish little or no water to herbaceous vegetation; these strata are fed by subterranean currents of water often coming from a great distance. Further, this water which existed in the deeper strata, being effused into the atmosphere, afterwards falls as dew, fog, or rain, and thus augments the quantity of water which the surface of the soil receives even at remote distances.

The quantity of water imbibed by the roots is such that it is difficult, in fact, to make anything grow near trees. Several causes prevent it. The earth which envelopes the roots nearest the surface is often in a certain state of desiccation; it loses by degrees its nutritive principles, its lime, &c.; it becomes dense, and, no longer containing aught else than clay and sand, acquires compactness, and is then more permeable.

It has now been shown, 1st, that there exists a difference between evaporation on a naked and on a sodded soil; 2d, that there is such a difference also in regard to a sodded soil and a wooded one, with the advantage in favor of the latter that it better facilitates infiltration of the water; 3d, that the quantity of water imbibed by the roots does not parch the soil, since, after exhalation, it again falls in the state of fog, dew, or rain. Desiccation only takes place when the soil is exhausted.

Let us see now to what point the conclusion of M. Beugnot, that the clearing away of woods is never prejudicial to salubrity, has its foundation in fact. This conclusion is true if the soil is siliceous or calcareous and the subsoil permeable; but it is not so if both are argillaceous, for the roots are no longer present to facilitate infiltration, unless indeed drainage is used to remove the stagnant water. Of this, Sologne, La Brenne, and Dombes are examples. Nor is it true if the woods which are removed existed in the proximity of swamps producing pestilential miasms, like the Pontine marshes.

Let us next consider the calorific influence of forests. This influence has been established as follows by Humboldt and the meteorologists: They screen the soil from solar radiation, preserve a greater humidity therein, and promote the decomposition of the leaves and twigs, which are converted into humus; they produce frigorific effects through the strong aqueous transpiration of the leaves, and by multiplying, through the expansion of the branches, the surfaces, which, acquiring heat by the action of the solar radiation, are again chilled by the nocturnal radiation. In relation to this latter action, positive experiments demonstrate that the stratum of air in contact with a prairie or a field covered with grass or with leafy plants is cooled, all else being equal, under the nocturnal radiation, to the amount of several degrees, sometimes from 6° to 7° or 8° (10° to 15° F.) below the temperature of the air at some metres higher up; while nothing similar takes place on a denuded surface, which grows warm or cool according to the nature of the parts composing the soil. We will add, however, that, inasmuch as the leaves as well as the trunk and branches acquire heat under the solar influence and preserve during the night a portion of that heat, this effect must naturally counterbalance that resulting from the nocturnal radiation. Until now, no account has been taken of this effect of solar radiation upon trees, although it exerts a considerable influence on the temperature of the air beyond the woods as within them. To explain the calorific influence of trees on the temperature of the air, it is necessary, therefore, to join to the older observations those which have been more recently made on the temperature of the air at different heights in the neighborhood and at the periphery of trees.

Humboldt and Bonpland, recumbent on the grass during the fine nights of the tropics in the plain of Venezuela and the lower Orinoco, experienced a humid coolness when the strata of air at a height of 1 or 2 metres (3 or 7 feet) had a temperature of 26° to 27°, (79° to 80° F.) In the equatorial and tropical regions, where the nocturnal radiation acts with so much force by reason of the serenity of the sky, the increase of temperature, as we ascend, is manifested as in middle latitudes, but to a much greater height. Hence, in the equatorial zone, no change is observed in the vegetation from the level of the sea to the height of 600 metres, (1,969 feet;) and beyond this, even to an altitude of 1,200 metres, (3,937 feet,) we still recognize the flora of the tropical zone.

We can now explain why, under our latitudes, certain products of culture fail in the depressions of the surface and succeed upon hills,

and for what reason vegetables are overtaken by frost in low situations and are exempt from its effects at heights a little more elevated. M. Martins observed a fact of this kind in the Botanic Garden of Montpellier. Laurels, figs, olives, nearly all perish in the lower parts of this garden, while, under conditions of shelter wholly similar, they are safe at an elevation greater by only a few metres. Do we not know also that vines planted on the acclivities of hills produce better wine than those which grow at the bottom, on account of a more perfect maturity?

Experiments which we have made with the electric thermometer evince quite satisfactorily this remarkable property, that the temperature of the air rises from $1^m.33$ (4 feet 4 inches) above the soil to $21^m.25$ (68 feet 10 inches) at the summit of a chestnut tree, and probably from this summit upward to a certain height whose limit has been fixed by M. Martins and other meteorologists; for the leafy periphery of trees must be supposed to act like the soil covered with low plants, by reason of its great absorbing and emissive power. The mean differences between the temperatures of the two stations have been verified at the Jardin des Plantes, during several years:

From $1^m.33$ to 16 metres	$0^o.420$
From 16 metres to $21^m.25$	$0^o.580$;

clearly showing the influence exercised by low plants and the periphery of trees on the temperature of the ambient air through the effect of calorific radiation. Let us now inquire what the influence of the body of the tree—that is to say, of the trunk and branches—may amount to. Every body, not excepting trees, immersed in air grows warm or cold, and partakes consequently, more or less, in the variations of the temperature experienced by the ambient medium, the effects produced depending on the state of the surfaces of the body, on its conducting power, and its specific heat. The experiments whose results we are about to report, as detailed in several memoirs which we have had occasion to present to the academy, (1861–'64,) furnish the clearest proof of the above proposition. Some of those results are as follows:

On examining the variations of temperature in the interior of a maple, $0^m.4$ ($1\frac{1}{2}$ inch) in diameter and situated in a group of other trees, it was found that, during the months of August, September, and October, the mean temperatures presented no sensible difference with that of the air except in September, although the variations in the tree were in amount very nearly one-half of those of the air.

The temperature in a tree is far from being the same in all its parts. If the leaves and branches promptly assume an equilibrium of temperature with the air, not the less promptly does the trunk conform therewith, and that to a depth of $0^m.1$, (4 inches.) The effects are different in trees exposed to the solar radiation, according to the proximity or remoteness of objects which absorb and radiate heat: a plum tree placed near a wall, 2 metres (7 feet) thick, was covered, in the month of July, with leaves and fruit; the tree was 6 metres (20 feet) in height, and in diameter, $0^m.35$, (13 inch.) The difference between the maximum and minimum of temperature had, for several days, been from 24^o to 25^o, and the temperature at the interior of the tree had ascended to 37^o, (99^o F.;) such a state of things could not long exist without weakening the tree, hence the leaves withered by degrees, the fruit fell off, and everything announced the approach of death, which took place a month later; thus was produced an effect which gardeners call a heat stroke, (*coup de chaleur.*)

We see, therefore, that a tree becomes heated in the air like an inert body, and the more rapidly in proportion as its mass has less volume

and its bark a more considerable absorbing power; so true is this that when the trunk of a plum tree was enveloped to the height of 2 metres (7 feet) with tin, which possesses strong reflecting properties, the temperature of the air being perceptibly the same as in the preceding case, the difference between the maximum and minimum descended from 13°.07 to 5°,2. (23° to 10°.) It will be seen from this that the temperature had become more uniform in the plum tree. On removing the envelope, the difference between the maxima and minima increased and became what it had been before.

Metallic envelopes or those of straw diminishing in trees the variations of temperature and rendering the movement of heat more regular, it will readily be conceived that the nature and thickness of the bark must exert a great influence on the calorific state of trees. Experiments made on the *Opuntia* and on other plants tend to show that the leaves and small branches are promptly brought into an equilibrium of temperature with the ambient air. On comparing the mean temperature of the air with that of the interior of a chestnut tree having a diameter of $0^m.5$, (20 inches,) it has been found that the mean of the temperatures observed in the tree, during a period of thirteen months, was superior by 0°.36 to that of the air at its surface, and by 0°.83 to the temperature of the air at the north and in the shade; this difference is owing probably to the fact that the thermometer was placed to the north and sheltered from the sun, while the tree was shielded from the north winds by a neighboring building, and was exposed moreover to the solar radiation. Experiments made on other trees show that the principle of equilibrium of temperature between the air and the trees shifts with the lapse of more or less time, and so much the more rapidly as the variations in the air are less frequent. In winter and autumn the difference is at a minimum, and in spring and summer it is at a maximum. The maximum of temperature in the air takes place, according to the season, between 2 and 3 o'clock in the afternoon, while in the tree it occurs after sunset. If regard be had to the seasons, it will be found that it is in summer especially that the maximum is more marked; it does not occur till about nine o'clock in the evening.

The heat disengaged in the organs and tissues of plants interposes but very feebly as regards their proper temperature, which is almost wholly of extrinsic derivation; for its principal cause, we must look to the solar radiation and the temperature of the air. The diurnal variation of temperature in the air is easy to determine, since it is the difference between the maximum and minimum of the day. To find this variation in a tree is a matter of difficulty, but we may arrive at it, in at least an approximate manner, by the following means:

Observations on temperature were made at Geneva, from 1796 to 1800, at the rising and setting of the sun, and at 2 o'clock p. m., in the air to the north and in the interior of a chestnut tree $0^m.6$ (24 inches) in diameter; the maxima and minima could be obtained by combining the temperatures at 2 o'clock and at the rising and setting of the sun, the maximum taking place about or after the setting of the sun, as was said above, and the minimum about the time of its rising; the difference obviously gives the variations within the tree. By discussing the variations thus obtained in the air and in the tree, it was seen that, during the years 1796, 1797, and 1798, the variations were, on a mean, more than five times greater in the air than in the tree.

In the observations made at the Jardin des Plantes, from December, 1858, to July, 1859, it was ascertained that the means of the variations of temperature in the air and in the tree were in the ratio of 3°.80 to

0°.81, that is to say, that they were 4.7 times greater in the air than in the tree, instead of 5.89 as was realized at Geneva. This difference depends evidently on the bad conductibility of the wood, which does not permit the variations of temperature in the air to be rapidly transmitted into the tree; it is easy to conceive that variations in the air distinctly marked, but of short duration, cannot become appreciable in the tree.

The leaves and young branches of trees, and the humbler plants which cover the meadows, existing under the same conditions as regards warming and cooling, produce the same effects of radiation; it is in the boughs of a certain bulk and in the trunks, therefore, that we must study the influence exerted by the proper temperature of the plant on the ambient temperature. A green stem should be considered, in fact, as a body covered with an envelope possessing a great emissive and absorbent power, by virtue of which its temperature is lowered or elevated incessantly through the effect of the radiation into space or of the solar radiation; but when the parenchymatous tissue is replaced by a cortical tissue, the *lignum* which is beneath being humid and a worse conductor in a transverse than longitudinal direction, the movement of heat is then effected very slowly, and brisk changes of temperature are no longer observed in the interior as in the case of the young branches. From the above it will be seen that the variations being much less in the stem of a tree of a certain volume than in the air, if the temperature of the air varies even to a wide extent, but the variations are at the same time of brief duration, the calorific state of the tree is but little affected thereby. In the contrary case, the tree finally assumes an equilibrium of temperature with the air.

Every vegetable has need of a certain degree of heat in order for its tissues to perform their functions; when the temperature rises gradually, the parts dilate; the evaporation and circulation of the sap is accelerated; the lowering of the temperature produces contrary effects. On the other hand, alternations of heat and cold give a new activity to vegetation; thus under the tropics, the great variations of temperature during the day and night, in that part of the air which envelops the trees, being equally manifested in the interior of the trees, this state of things proves eminently favorable to the forest vegetation.

The atmosphere is the source from which all plants derive the heat of which they have need in order to germinate, develop themselves, and accomplish all the phases of their existence. The mean temperature of a place, the daily variations and the extremes of the temperature of the air, are the calorific elements to be principally taken into consideration in the phenomena of vegetable life and in researches relative to the calorific influence of forests and of woods in general upon climate. The heat produced in the tissues in which the transformation of the sap is effected does not act sensibly on the temperature of vegetables; at least it is not appreciable by our instruments; what they possess is borrowed.

We have ourselves undertaken several series of observations on temperature in different localities, both within the woods and without, to a certain distance, in order to ascertain the influence which forests exert on the mean temperature. The results which we shall obtain will form the subject of another memoir.

It is proper here to remark that plants possess of themselves the faculty of resisting for a certain time an extreme degree of refrigeration without suffering organic lesion, as we have ascertained in a series of experiments which leave no doubt on that point. We have been thus led to believe that there exists in the organization of vegetables a cause

independent of conductibility, which strives against a reduction of temperature below zero, and preserves them for a certain time from the disastrous effects of excessive cold. The action varies with the diameter of the tree, and probably with the species to which it pertains.

In northern regions the temperature of vegetables compared with that of the air is very remarkable. M. Bourgeaud, under the 58th degree of latitude, at places where the temperature descends in winter below the degree of congelation of mercury, that is to say to more than —40°, has substantiated the following facts: First. In the *Populus balsamifera* and *Abies alba*, during eight months, from November, 1857, to June, 1858, at 9 o'clock in the morning, the moment at which he supposed the temperature to be very nearly a mean, the mean temperatures of the air and the tree were the same; which accords with the observations above spoken of, and is in conformity with the principle that the temperature of plants unceasingly tends to form an equilibrium with that of the ambient air, notwithstanding the efficient causes which are incessantly in action to increase or diminish it. Second. The monthly temperatures presented little difference in the tree and in the air, although there were very great differences in the maxima and minima; in the month of January, for example, the maxima and minima were in the air +6°, (43° F.,) and —34°.60, (—29° F.,) and in the poplar —2°.20, (28° F.,) and —29°.70, (—21° F.) Third. During the eight months of observation the mean temperature in the soil, at a depth of $0^m.913$ (3 feet) and $0^m.609$, (2 feet,) was twice as high as in the air.

The thaw takes place ordinarily in May, spring at once commences, and soon after summer arrives; the rapidity of vegetation is such that the cereals sown in the month just mentioned are reaped toward the end of July; blossoms appear on the poplar when the temperature of the air is at +13°.47 (56° F.) and while the earth still freezes at a depth of $0^m.609$, (2 feet,) and $0^m.913$, (3 feet.) The leaves display themselves in the first days of June, when the roots are buried in strata of earth where the temperature is still at zero, (32° F.;) like effects are produced when the branches of the vine are introduced into a conservatory while the stalks and roots are in the ground outside; the buds and even leaves begin to be developed when it is freezing externally at 8° and 10° below zero, (18° and 14° above zero F.) We have here a new proof of the influence of the temperature of the air upon that of trees, showing that, even when the roots are in frozen earth, vegetation may proceed under that influence. The *Populus balsamifera* and *Abies alba*, as well as other species, undergo exposure to a cold of —40°, without injury to their organization, but the roots of these trees are in strata of earth which are not sensibly reached by the frost. A proof that there is here a certain resistance to cold is the fact that the greatest minima of temperature, being —34°.60, (—29° F.) in the air, were, in the poplar, only —29°.70, (—21° F,) and that the temperature has been twice as high in the tree as in the air.

After having stated the relations which have been found to exist between the temperature of the air and its variations, as compared with those of vegetables, it remains for us to show what temperature of the air has been realized above trees of large growth, such as a chestnut $21^m.25$ (70 feet) in height, at the summit of which had been placed one of the solderings of an electric thermometer in contact with the leaves. Multiplied observations have demonstrated that the temperature of the air above the chestnut tree depends chiefly on the calorific state of the leaves and branches which warm or cool the ambient air more or less, according as they have been exposed a longer or shorter time to solar radiation, or to nocturnal radiation.

A tree (trunk, branches, and leaves) must, as has been said above, become warmer or cooler, like all bodies immersed in air, according as the sun is above or below the horizon. In the first case, it grows warm from the effect of the solar radiation; in the second, it grows cool from that of the nocturnal radiation, and this process goes on until the tree acquires an equilibrium of temperature with the surrounding medium. When nocturnal radiation commences, if the sky be without clouds, in proportion as the upper branches and leaves become cool, those which are underneath yield up their heat in succession to those above through the process of radiation. From this it will readily be conceived that the strata of air which envelop the tree retain during a great part of the night a temperature higher than that of the strata of air which are remote from it.

A tree which has been warmed by the effect of solar radiation so far acts as a body imparting warmth to the air, that, when a rain occurs suddenly, the temperature of the air is more lowered at some distance from the tree than immediately around its periphery. Of this we will cite an exemplification. On the 9th of May, at one o'clock, after a strong insolation or free exposure to the sun's rays, the following temperatures were observed:

Temperature above the chestnut tree	19°.4	(67° F.)
Temperature at a certain distance	18°.3	(65° F.)
Difference	1°.1	(2° F.)

Half an hour afterward, a rain fell, and the temperatures changed:

Temperature above the chestnut tree	17°.5	(64° F.)
Temperature beyond it	15°.2	(60° F.)
Difference	2°.3	(4° F.)

Thus, in the interval of half an hour, the air which surrounded the tree had been cooled by only 1°.9, (3° F.,) while that which was a little distant from it was cooled to the extent of 3°.1, (6° F.;) it follows that the tree had radiated heat so as to impart warmth to the ambient atmosphere. The sun having reappeared after some moments, the temperature at both stations rose, but somewhat less above the chestnut tree than at a certain distance from it. These temperatures, at 3 o'clock, were as follows:

Above the tree	20°.8	(69° F.)
At a certain distance	19°.2	(67° F.)
Difference	1°.6	(2° F.)

To give an idea of the warmth imparted to the air through the presence of leaves, we will take, for an example, the temperature of the air in July, 1863, at 9 o'clock in the morning, and at 3 and 9 o'clock in the evening; for the monthly mean the following results were obtained:

At 9 o'clock in the morning	21°.56	(71° F.)
At 3 o'clock in the evening	26°.76	(80° F.)
At 9 o'clock in the evening	19°.20	(67° F.)

Here we see that the temperature of the air was at its maximum at 3 o'clock, and that it had diminished by nearly a fourth at 9 in the evening. The radiation of the internal heat of the trunk and branches of the tree continued, on the other hand, to repair the losses sustained by

the leaves subjected to the influence of the nocturnal radiation until 6 o'clock in the morning, when the temperature was found to be the same at 1m.33 (4 feet) above the soil to the north and south, at 16 metres (53 feet) and at 21m.25 (69 feet) on the summit of the tree. This is the period of the day when the celestial radiation has ceased to be preponderant, and when there is an equilibrium between the effects of the terrestrial radiation and those of the celestial radiation.

In July, 1864, the results obtained were:

At 9 o'clock in the morning	21°.04	(70° F.)
At 3 o'clock in the evening	25°.94	(78° F.)
At 9 o'clock in the evening	19°.00	(76° F.)

The progressive reduction again continued till 6 o'clock in the morning, when the temperature was the same at 1m.33 (4 feet) above the soil to the north and south, and also at 16 metres (53 feet) above the soil, and was equal to 15°.50, (60° F.) If the months of January, 1863 and 1184, be taken we have—

	1863.		1864.	
At 9 o'clock in the morning	4°.57	(40° F.)	—0°.05	(31° F.)
At 3 o'clock in the evening	7°.41	(45° F.)	+3°.30	(38° F.)
At 9 o'clock in the evening	5°.13	(41° F.)	0°.00	(32° F.)
At 6 o'clock in the morning	3°.19	(38° F.)	—1°.08	(30° F.)

It is thus seen that, whether we take the trees with or without leaves, the heat acquired during the day diminishes till 6 o'clock in the morning.

We see now that it may be assumed as an ascertained fact that trees, exposed to the solar and celestial radiation, impart heat or cold to the contiguous strata of air, a property which had not previously been suspected; it was supposed, on the contrary, that the evaporation which takes place by means of the leaves was always a source of refrigeration; this may indeed exert an influence, but it is not the predominant cause. This question, however, will be resumed in another memoir.

The experiments above spoken of were made on isolated trees, but the results have been the same on groups of trees sheltering one another, so as to form an obstacle to the direct action of the sun; only the elevation of temperature in the trunk has been found to be less, all else being equal, than when the tree was isolated. In fact, forests, coppices, and groups of trees must observe the same laws as the single chestnut tree; but the effects of heat, of which we have been speaking, vary according to the height of the trees, the extent of their branches, and the mass of leaves with which they are charged. What consequences should be inferred in relation to the influence exerted by forests on the local climate? This question we shall answer on another occasion. We shall content ourselves here with saying that it is necessary to have regard to the nature of the soil, as to whether it be dry or humid, to the greater or less facility with which the air circulates, to the exposure and other indeterminate causes which vary according to localities. But from the fact that the wood, under the influence of the solar radiation raises the temperature of the ambient atmosphere, and lowers it under the effects of the nocturnal radiation, must we not infer that the stratum of air which has been heated gives rise during the night to a double current; an upper one of warm air and a lower one of cool air which descends toward the ground? It may be that the warm air, being driven by lateral currents, has a tendency to ameliorate the temperature of surrounding parts.

Under the tropics, and especially under the equator, where the solar rays act with the more force as they are less inclined, trees must pro-

duce in a high degree the effects indicated above; effects which the neighboring strata of air cannot fail to manifest. On the other hand, the nocturnal radiation, which is very great under a sky almost without clouds, must act powerfully in hastening the refrigeration of the leaves.

The following fact is, to a certain point, referable to the heat which woods emit when they have been warmed by solar radiation. Every one knows that at noon of a hot summer day the air in dense woods is almost of a stifling heat. It is usual to attribute this effect to the absence of currents of air, and that, to a certain extent, may be true; but a concurrent cause of no little efficiency is the fact that, when the leaves and branches of trees have for some time been exposed to the calorific action of the sun's rays, they themselves become foci of heat.

We have thus explained the sort of influence exerted by trees on the temperature of the air which surrounds the trunk and branches; yet we cannot confidently deduce the conclusion that the mean temperature of the place is further ameliorated by this state of things. To aid us in solving this question, it is necessary to consult the observations of temperature made in wooded and unwooded places, situated under the same latitude, having the same geological conditions, and at the same height above the level of the sea.

Jefferson, in a work translated (1786) by the Abbé Morellet, drew, from observations made at Williamsburg and Monticello, (Virginia,) the conclusion that, since the clearing away of the forest, a very sensible change had taken place in the climate; the heat, as well as the cold, had become less vehement than before, as was testified by persons of no very advanced age. The snows, he says, are less frequent and less abundant, often not remaining in the valleys more than two or three days, and very rarely a week, while, within the memory of the living, they are known to have been frequent, deep and durable. By old persons it is stated that the ground was covered with snow three months in the year, and that rivers, which now freeze very rarely, were usually congealed every winter. These assertions, it will be seen, are based on testimony against which we must be on our guard, for it may well be that years of extraordinary inclemency were taken for those of an average temperature. Let us turn to observations which inspire more confidence, such as those discussed by M. Boussingault, and made by MM. Boussingault himself, Humboldt, Roulin, Rivero, &c., in localities comprised between the 11th degree of north latitude and the 5th degree of south latitude, where the celestial radiation prevails, during the night, in all its force.

The mean temperature, by reason of the slight variations in the course of the year, is immediately given by that which is presented by the earth, in the shade, at 3 decimetres (1 foot) below the surface. Observations show that the temperature of the torrid zone varies from 26°.5 (80° F.) to 28°.4, (83° F.,) and that the abundance of forests and humidity tend to the refrigeration of the climate, while dryness and aridity produce contrary effects. These effects have been observed at different heights on the Cordilleras, where we find the mean temperatures of temperate regions. It has been asked whether this is the case in localities wooded and denuded of wood, situated beyond the tropics, where the mean temperatures being the same, the means of summer and winter are different? No observation has yet been made as to this point.

Observations subsequent to the preceding tend to show, on the contrary, that disboscation on a great scale does not sensibly change the mean temperature. Humboldt has collated a great number of thermometric observations made at different points of North America, in order

to ascertain if the mean temperature had undergone changes after a considerable lapse of years. For about sixty-three years, from 1771 to 1834, he tells us, thermometric observations had been maintained at thirty-five military posts, so that we have far more exact ideas on the climate of North America than existed in the times of Jefferson, Barton and Volney.

These stations were distributed over a space of 40° of longitude and extended from the point of Florida and Thompson's Island, under 24° 35′ of latitude, to Council Bluffs, on the Missouri. On discussing the observations communicated to him, Humboldt arrives at the following conclusions:

These observations, he says, tend to demonstrate, contrary to an opinion quite generally adopted, that, since the first establishment of Europeans in Pennsylvania and Virginia, the climate, on either side of the Alleghanies, has not, in consequence of the destruction of numbers of forests, become more uniform, more mild in winter and cool in summer, than it was before; nevertheless, as Humboldt himself acknowledges, denudation ought to ameliorate the mean temperature by effecting the disappearance of three frigorific causes; first, the protection of the ground from the solar radiation and the maintenance of a greater humidity; secondly, the production of aqueous transpiration by the leaves; thirdly, the multiplication by the expanded branches of the surfaces which are cooled through the effect of nocturnal radiation. M. Boussingault, as we have previously seen, has arrived at contrary conclusions, indicating that the abundance of forests and the humidity thence resulting tend to render the climate cooler, and that dryness or aridity produces an opposite effect.

It might be, however, that, the mean temperature remaining the same, the distribution of heat in the course of the year may be changed, and that thus the climate may have been modified; but it will not suffice to invoke the authority of documents relating to cultivation at the present time, for these documents will not bear a serious examination, as we have shown in our treatise on climates.

Still, it is possible that a step in advance may be made by taking into consideration observations which have thus far not received due attention. The observations regarding temperature which we have made in the interior of single trees and at the periphery of their branches show, as has been already said, that trees are affected like all bodies exposed or unexposed to solar radiation; that is to say, that they are heated or chilled according to their absorbent, reflecting, and conducting powers. These observations evince, moreover, that their calorific state depends in great part on the solar action. What can we thence infer in relation to the influence of trees on the temperature of the air and the changes which that temperature undergoes as the effect of denudation? These changes result not only from the cause of which we have been speaking, but further, we repeat, from the nature of the soil, according as it is dry or humid, calcareous, sandy, or argillaceous. Let us analyze the effects which may thus be produced.

We will first consider a wooded soil: The trees, as has been just stated, become heated or cool; but what results from this when the soil is dry and when it is humid? If the former, it will be without influence; if it is humid, the evaporation of water will maintain a constant humidity, the degree of which will depend on the temperature which the trees have acquired and which will be independent of that resulting from the exudation by the leaves. The humidity caused by trees, when other things are equal, will be greater in wooded countries with an argillaceous

foundation which retains the water, because the roots do not pierce the subsoil or do so with difficulty, than in sandy formations which favor the infiltration of water. In the latter case, the humidity proceeds solely from the transpiration of the leaves.

What occurs when a country is cleared of its woods, supposing the soil either pervious or impervious? The effects which result depend on the composition of the soil and on its absorbent, radiating, and conducting powers. Of these an idea may be formed from the researches of Schubler. Commencing with the calefaction of lands exposed to the sun, the following are the relations which are found to exist between different soils:

Designation of earths.	Maximum temperature of the upper stratum, the mean temperature of the air being 100°.	
	Humid soil.	Dry soil.
	Degrees.	*Degrees.*
Siliceous sand, yellowish gray	37.25	44.75
Calcareous sand, whitish gray	37.38	44.50
Pure gypsum	36.55	43.62
Poor yellowish clay	36.75	44.12
Fertile clay	37.25	44.50
White calcareous earth	36.63	43.60
Grayish-black humus	39.75	47.37
Grayish-black garden mold	37.50	45.25

It will be seen that color and humidity are the causes which exert the greatest influence. The differences of temperature due to these causes and that of the ambient air may, for the same soil, amount to 14° or 15°.

If we pass to the capacity of retaining heat, it will be found that all else being equal, the siliceous and calcareous sands, compared in equal volumes with the different argillaceous earths, with lime finely comminuted, with humus, with arable and garden earths, are the soils which conduct heat more imperfectly. This is the reason why sandy formations, in summer, preserve, even during the night, an elevated temperature. We may conclude from this that when a sandy tract is cleared of wood the local temperature must be raised, and with the greater reason, inasmuch as the cause of refrigeration exists no longer. After the sands come in succession argillaceous, arable and garden soils, and finally humus, which occupies the last rank. Representing by 100° the capacity which calcareous sand possesses of retaining heat, the following are the ratios observed:

	Degrees.
Calcareous sand	100
Siliceous sand	95.6
Argillaceous earth	68.4
Garden soil	64.8
Humus	49.0

It has been further established that the capacity of retaining heat is proportional to the bulk of the particles. It is on this account that land covered with siliceous stones grows cool more slowly than siliceous sand, and that pebbly soils are better adapted for maturing the grape than chalky and argillaceous formations which cool rapidly. From this

it appears how important it is, in the examination of the calorific effects resulting from disboscation, to have regard to the physical properties of the soil, when it is once denuded. Here probably is to be found the reason why the conclusions which Humboldt has drawn from the thermometric observations made at stations in North America, no attention having been paid to the nature of the soil of the denuded surface, are not the same with those at which M. Boussingault has arrived by taking that condition into consideration.

It has been competently proved, then, that the disboscation of a soil formed of a siliceous, pebbly sand, must raise the mean temperature of the air more than any other formation, at the same time that it causes the disappearance of a source of humidity; while, if the soil is argillaceous, whether dry or humid, the capacity of warming the air and retaining heat is, relatively to the former, in the ratio of 68.4 to 100. The calorific effect must be considerably less from the denudation of a dry formation.

We see now in what manner we should consider the influence of disboscation on the temperature of the air. The effects, however, are so complex that we can only determine the resultant by the help of diurnal observations of temperature; it is necessary besides to collate the maximum and minimum temperatures, which play a very important part in the constitution of climates, and to have regard to the nature of the soil. We shall resume this question on an early occasion.

The following illustration is of a nature to give an idea of the influence which forests may exert on the climate of a vast region. The presence of extensive forests in the tropical portions of the African continent, situated under the meridians of the western part of Europe, would probably modify the ascending current of warm air which at present results from the heating of a sandy surface, and which descends upon the middle latitudes of Europe. If, in the lapse of centuries, the sands of the Sahara should become covered with woods, these sands would not be heated to so high a degree as at the present epoch; consequently the winds of the south, which now mollify our climate, having no longer so high a temperature, would render it more rigid. To be satisfied of this it is sufficient to consider the state of things on the American continent, where the tropical regions are occupied by vast forests, immense savannas, or great water-courses; the descending currents of warm air cannot moderate the climate of countries situated in the middle latitudes of North America as much as the warm currents coming from the Sahara mitigate the countries of the eastern continent situated under the same latitudes. And here is precisely the reason why the western continent, under corresponding latitudes, is colder than ours, judging from the objects of culture and the course of the isothermal lines in each.

Nor does it suffice to study the calorific influence of the extirpation of woods upon climate; it is further necessary to inquire into the action which it exerts on the sources of streams, and the physical effects produced in mountainous countries on a denuded soil, as well as those resulting from such denudation in argillaceous and humid formations. Another observation we will make, as not being without some importance: It has been previously seen that a tree becomes warm or cool like an unorganized body, and that in proportion as the leaves are cooled at night by the effects of the nocturnal radiation, the loss of heat is repaired by a radiation transmitted by the trunk and branches; this state of things, which has not been hitherto noticed by physicists, hinders the air from being chilled as much as if the calorific radiation of

the trees had not taken place. The influence of woods in cooling the air is not as great, therefore, as has been supposed. The state of the soil, moreover, singularly modifies that influence.

EFFECTS OF THE CLEARING AWAY OF FORESTS ON SPRINGS AND WATER-COURSES.

The effects of disboscation on the sources and quantities of living water which irrigate a country are of most important consideration, and hence require serious attention. The difficulty in verifying these effects is the greater inasmuch as it is impossible to say, *a priori*, whether a forest or portion of a forest, destined to be cleared away, contributes to supply such or such a source, such or such a river. Springs are owing, in general, to the infiltrations of rain-water in a pervious formation, through which this water sinks until it meets with an impervious stratum, flowing over the latter when it is in an inclined position, and eventually rising in streams or fountains. The water of wells has the same origin. Large springs are ordinarily found in mountainous regions.

Forests also contribute to the formation of springs, not only by reason of the humidity which they produce, and the obstacles which they oppose to the evaporation of the water which falls on the surface, but further because of the roots of the trees, which, by dividing the soil, render it more pervious and thus facilitate infiltration. A great number of illustrative examples have been cited, but we shall here adduce only a few which may be regarded as among the most remarkable.

Strabo informs us that it was necessary to take great precautions to prevent the country of Babylonia from being submerged. The Euphrates, which begins to swell, he tells us, at the close of spring, when the snows melt on the mountains of Armenia, overflows at the beginning of summer, and would necessarily form vast accumulations of water on the cultivated lands were not the superflux turned aside by means of trenches and canals. This state of things exists no longer. M. Oppert, who some years ago traveled through Babylonia, reports that the volume of water conveyed by the Euphrates is much less than in past ages, that inundations no longer occur, that the canals are dry, the marshes exhausted by the great heats of summer, and that the country has ceased to be insalubrious. This retreat of the waters can only be attributed, as he found means to satisfy himself, to the clearing away of the forests on the mountains of Armenia.

The effects in question, though denied by some, are not the less incontestible, as is shown by examples which I proceed to report and which rest upon observations worthy of entire confidence.

De Saussure (*Voyage dans les Alpes*, t. ii, ch. 16) long ago pointed out the diminution of water in the lakes of Switzerland, especially in Lakes Morat, Neufchâtel, and Bienne, as a consequence of the clearing away of the forests. Choiseul Gouffier was not able to distinguish in the Troad the River Scamander, which was still navigable in the time of Pliny. Its bed is now entirely dry; but the cedars also, which covered Mount Ida, whence it took its source, as well as the Simois, exist no longer.

M. Boussingault, (*Annales de Chimie et de Physique*, t. xiv, p. 113,) who studied this subject during his sojourn in Bolivia, selected as the subject of his observations the lakes situated in the plains or on different steps of the mountains. The valley of Aragua, province of Venezuela, situated at a short distance from the coast, has a very favorable climate, and is of great fertility. It is closed in on every side, the rivers which traverse it having no issue toward the ocean; by their union

they form the Lake of Tacarigua or Valenciana, which, at the time when Humboldt saw it, had been undergoing for some thirty years a gradual desiccation, the cause of which was unknown. Oviedo, the historian of Venezuela in the sixteenth century, relates that the city of Nueva Valencia was founded in 1555, at the distance of half a league from the Lake of Tacarigua, from which, when Humboldt was there in 1800, it was distant 2,700 toises, (3½ miles,) a proof of the retreat of the waters confirmed by a number of facts. According to the celebrated traveler just named, the diminution of the waters was directly attributable to the clearing away of numerous forests.

In 1822, M. Boussingault learned of the inhabitants that the waters of the lake had exhibited a very sensible elevation; lands which were before cultivated were then submerged. It is to be noted that, for the term of twenty-two years previous, the valley had been the theater of bloody contests during the war of independence; the population had been decimated, the lands had remained untilled, and the forests, which grow with prodigious rapidity under the tropics, had eventually occupied a great part of the country. We see here the influence of woods on the quantity of water which flows or settles in a country, since lakes which had been exhausted by the removal of forests were again replenished by their restoration.

M. Boussingault cites several examples which lead to the same conclusion in regard to the influence exerted by great masses of wood on the living waters of a country. We shall quote two of the most remarkable. In 1826, the metalliferous mountains of Marmato presented only some miserable cabins inhabited by negro slaves. In 1830, this state of things no longer existed; there were numerous work-shops and a population of 3,000 inhabitants. It had been found necessary to level much wood; the denudation had proceeded but for two years, and already a diminution was perceptible in the volume of water available for the labor of the machines. Yet a pluviometer proved to M. Boussingault that the quantity of water which had fallen in the second year was greater than that which fell during the first. This fact tends to show that disboscation may diminish and occasion the disappearance of sources, though, from that circumstance, no inference is warranted of the fall of a less quantity of rain. The second example is derived from the table-lands of New Grenada, at an elevation of from 2,000 to 3,000 metres, (6,500 to 9,800 feet,) where there is a temperature during the whole year of 14° to 16°, (57° to 61°F.) The inhabitants of the village of Dubaté, situated near two lakes, which were united sixty years ago, have witnessed the gradual subsidence of the waters, insomuch that lands which, thirty years since, were under water are now subject to culture. The examination of local conditions and other investigations made by M. Boussingault, convinced him that this change was due to the disappearance of numerous forests which have been cut down. At the same time other lakes, such as that of Tota, at a short distance from Fuquené, situated in localities where the woods have been undisturbed, have undergone no diminution of their waters. M. Desbassyres de Richemont has also discovered that there exists in the Island of Ascension, at the foot of a mountain, a fine water source, which became dry in consequence of the denudation of the neighboring heights, but has been restored since the forest was again allowed to grow.

To complete the documents which may serve for the elucidation of this question, there are still some important observations to be brought forward. M. Berghaus (*Cours d'Agriculture de M. de Gasparin*, t, ii, p. 146) finds that the volume of water in the Oder and the Elbe underwent

diminution, from 1778 to 1835 in the first of these rivers, and from 1828 to 1836 in the second, and that this diminution was so sensible that, should it proceed at the same rate, it would be necessary at the lapse of a certain period to change the construction of boats; here, however, statistical observations evince that this fact cannot be attributed to the extermination of the forests of the mountains. In order to explain it, inquiry has been made whether the quantity of rain falling in the different parts of Europe has not undergone a corresponding diminution, but the hypothesis has not been sustained. In fact, since 1689, during which interval the quantity of rain falling at Paris has been observed, a slight augmentation, rather than any diminution, has been verified. Cesaris has recognized the same increase for the city of Milan from 1763 to the present epoch; and a similar result appears, in regard to Rochelle and the basin of the Rhone. The supposition of a diminution of rain being hence untenable, it has been surmised that possibly the number of rain-falls may have changed, a conjecture founded on the generally admitted fact that a great rain furnishes more water to the river courses than the same quantity distributed over several days with intervals of dryness. But the discussion of the observations has afforded no confirmation of this view. It has been found necessary to fall back upon the changes produced in climates by the progress of cultivation.

It may happen, as has sometimes been the case, that concussions of the earth dry up the sources of streams, but this is not common. A great number of facts demonstrate, on the other hand, that the diminution is often an almost immediate sequence of extensive clearings. We would point especially to the instance already cited of the water-courses of Marmato. Nor are there other examples undeserving of a passing reference. The Romans were able to bring to Orleans the waters of the fountain of Etuvée, which at the present time is entirely dried up. Extensive excavations, made within a few years, have brought to light the foundations of Roman constructions where no source of water any longer exists; a stream, moreover, to the east of Orleans, which contributed to the defense of the city during the siege in 1428, and which was considerable enough to turn mills, has completely disappeared. Now, on that side of Orleans there were great forests, which have been cleared away. In consequence of these clearings the wells of the city have continued to yield less and less water, so that the municipal administration has been obliged, within a few years, to incur an expense of 300,000 francs ($60,000) in order to bring potable water from the source of the Loiret.

In the canton of Châtillon-sur-Loing there is a commune called Sainte-Geneviève-des-Bois, which would appear to have been once a tract of forest, but which presents to-day only small groves scattered here and there. A stream formerly flowed at the foot of the town where at present exists only its dried bed, never containing water except in winter.

In discussing the important question of the influence of disboscation on water-courses, we arrive at the following conclusions: 1. Extensive clearings diminish the quantity of spring or flowing water in a country; 2. It cannot yet be determined whether that diminution should be attributed to the less considerable quantity of rain which falls, or to a greater evaporation of the pluvial supply, or to both causes united, or to some new distribution of the water derived from rains; 3. The cultivation practiced in an arid and denuded country dissipates a part of the flowing waters; 4. In countries which have undergone no changes in cultivation the quantity of water in streams or from sources appears to be always the same; 5. Forests, while preserving such waters, economize and reg-

ulate their discharge; 6. The humidity which prevails in woods and the function of the roots in making the soil more pervious, should be taken into consideration; 7. The clearing away of forests in mountainous countries exercises an influence on the streams and springs in the lowlands, especially in the latter; 8. Hence the action of forests upon climate is of a highly complex nature.

With the means of securing salubrity now at our disposal, there is no occasion for apprehending unhealthy swamps as the result of the extirpation of forests. Nor need it be inferred that the denudation of a country entails sterility. As examples, England and Spain may be cited, which present, the one only 2 per 100 of wooded surface, the other 3.17 per 100. The former has a marine climate, marked by the frequent prevalence of southwest winds charged with vapor to the point of saturation, which produces fogs on the least lowering of the temperature. Spain has not a similar climate, but its most fertile parts are those watered by large rivers, while the great table-lands are absolute deserts.

From what has been said the question presents itself whether the extirpation of a great forest in the vicinity of a fertile plain possessing only springs of water, might not give reason to fear the desiccation of these springs in whole or in part and the consequent impoverishment of the country? The denudation of an arenaceous country may lead to the desolation of the neighboring plains through the incursions of the sand, as may easily be conceived from the explanation given by M. Chevreul of the formation of downs in the Landes of Gascony; the sand is here driven by the winds until it encounters an obstacle, when a barrier is formed which arrests the discharge of the waters; these moisten the base of the heap, and by capillary action cause the particles of sand to cohere and become fixed to the soil; the winds remove only the upper part, which, being carried forward, continues to form new downs until the plain in the end is wholly overwhelmed with sand.

A forest, interposed in the passage of a current of humid air charged with hurtful miasms, sometimes preserves from their influence any tract which is thus sheltered; while uncovered regions, as is exemplified in the Pontine marshes, are exposed to the baleful influence. Trees, therefore, tend to purify an infected air by absorbing or obstructing its pestilential constituents. Still another kind of action is exercised upon climate by the presence of forests: the trees of lofty growth which compose them withdraw electricity from the clouds, and thus to some extent neutralize the disastrous effects of storms.

The restoration of forests upon the mountains is an operation of prime necessity for the preservation of the latter; its advantages result: 1st, from the increased facility with which the rain-waters penetrate into the soil and even the subsoil, being traversed by roots which promote infiltration; 2d, from the effects produced by the resistance which forests oppose to the passage of masses of air saturated with vapors in motion, which promptly descend in rain on being forced upwards and compressed by the obstacle; 3d, from the humidity which generally prevails in the interior and in the vicinity of woods and which gives place to a precipitation of dew when the temperature of the air is lowered.

Of the transformation of lands from which the forest has been removed into marshes, some striking examples may be cited, and those not in Asia Minor, of which mention has been made elsewhere, but in France itself. It is to be observed that when trees are cut down, the roots of course die and the soil becomes more compact. La Brenne, situated between the Indre and the Creuse, presents a circular surface of more than 200 kilometres (125 miles) in circumference, or nearly 80,000

hectares, (197,680 acres.) The soil of this country, which is argilo-siliceous, rests on a substratum of impenetrable clay which resists the infiltration of water; it is thickly covered with pools, to which are attributed the intermittent fevers prevalent throughout the district. Ten or twelve centuries ago it was occupied by forests interspersed with meadows, watered by running streams and fountains, and there existed then neither pools nor swamps; on the contrary, it was renowned for the fertility of its pastures and the amenity of its climate. The disappearance of the forests was succeeded by collections of stagnant water which took possession of the now unproductive and worthless soil, and this to such an extent that in 1714, the tract of Bouchat-en-Brenne alone counted no less than one hundred and nine of them. (Piganiol de la Force, *Description de la France.*) A like state of things appears in Sologne, which represents a surface of 450,000 hectares, (1,112,000 acres,) and which has become proverbial for its insalubrity. The deplorable condition in which we see it did not always exist. Historical documents show that a great part of this country was of old clothed with woods. Their extirpation has been succeeded by accumulations of water, fens, and the attendant maladies. At the present day the removal of the forest need not involve so calamitous a consequence, for modern ingenuity has placed at our disposal the means of restoring salubrity and fertility to swamps and moor-lands of even long standing.

The effects produced in mountains clearly evince the action of roots in promoting the infiltration of rain-water and the alimentation of sources. In a mountainous country the extirpation of forests promptly leads to the formation of torrents. Of this the Alps furnish numerous examples. When, in fact, vegetation is left to develop itself freely on the sides of mountains covered with the detritus of rocks from the summit, dense forests of spruce and larch quickly occupy their flanks, and the interlacing roots form a net-work which binds and protects the soil. If clearings are inconsiderately made in the direction of the slopes the waters follow the course of the openings, and, carrying with them the vegetable deposit, rapidly excavate furrows. These furrows extend with time, and end by forming torrents. Nothing of this sort occurs where the woods have not been felled. All the eastern part of the department of the Hautes-Alpes presents numerous results of this kind.

We thus see that the presence of a forest on a surface of steep inclination counteracts the formation of torrents, while disboscation exposes the soil to their ravages. This effect it is easy to explain when the soil is once occupied by vegetation, first by the humbler plants, then by trees whose roots, forming a sort of felting, give consistence to the ground at the same time that the branches and leaves break the force of heavy rains. The trunks, the off-shoots, the brush-wood, multiply obstacles in the way of the currents which would otherwise furrow the earth. The effect of vegetation, therefore, is to give more stability to the soil and to distribute the waters over its whole surface, so as to prevent their following the drains in a mass, as would be the case if the earth were denuded. *The soil, being divided by the roots and covered with a porous humus*, absorbs a part of the waters which cease to flow down the slopes and are conveyed by percolation to the low grounds, where they serve to feed streams and fountains. Such are the benefits resulting from the presence of forests on mountains and inclined surfaces exposed to torrential rains.

ON METEORITES.

EXTRACT FROM A DISCOURSE, FEBRUARY 7, 1869, BEFORE THE SOCIETY OF NATURAL HISTORY OF WISCONSIN, BY DR. FR. BRENNDECKE.

[*Translated from the German for the Smithsonian Institution.*]

* * * As furnishing the finest exemplifications of the Widmannstäten figures, as well as the purest and rarest kinds of siderites, may be cited the meteorite of Braunau, the meteorite of Secläsgen, the Putnam meteorite of Georgia, and the Dörflinger meteorite found here in Wisconsin. According to the classification made by Professor Shepard, the last belongs to the order of the taniastic siderites, (ribbon siderites.) Besides this specimen, there has been adduced by Professor Shepard only one example of the order in question, which was found, in 1801, at the Cape of Good Hope.

In a report which, in the beginning of September, 1868, I had the honor, at the instance of the Wisconsin Society of Natural History, to lay before it, respecting the iron meteorite found in that State, and which contained the results of an exploration of the locality where the meteorite was found, conducted by Mr. C. Dörflinger and myself, it was stated that, in July, 1868, there was presented to the museum of the society, by its secretary, Mr. Dörflinger, a piece of iron of sixteen pounds weight, which had been found in Washington County, Wisconsin, by parties engaged in cultivating a farm. This piece, upon scientific investigation of its physical properties by Mr. Dörflinger, proved to be genuine meteoric iron. The surfaces ground and polished with a view to its examination, when treated with nitric acid, exhibited Widmannstäten figures of the greatest beauty and distinctness. A qualitative chemical analysis, conducted by the director of the mineralogical section of the society, Dr. G. Bode, confirmed the discovery. The place where the mass of meteoric iron was found is in section 33, Washington County, Wisconsin, on a small farm belonging to a farmer named Louis Korb. In the fall of 1858, Korb, in working his farm, struck with his plow against some hard object, which lay about ten inches under the earth. The supposed stone proved to be a mass of metallic iron of sixty-two pounds weight. The representation of this mass, as regards both its magnitude and form, lies before the society in the drawing executed by Mr. Dörflinger, at the place of discovery.

In the years immediately following that last mentioned, Korb found similar but smaller pieces of meteoric iron to the number of four, as I am informed, within a circuit of from two to three rods from the place where the first and larger mass was lying. One of these pieces is the iron meteorite of sixteen pounds weight presented by Mr. Dörflinger to the society. A second piece I procured, in conjunction with Mr. Dörflinger, at Cedarburg, where it had been kept until then. This weighs seven and three-quarter pounds. A third piece we obtained from the printing office at West Bend, where it had been for several years, but

without the least recognition of the nature of the mineral by any one either there or at Cedarburg. A fourth piece should have been at the Korb farm-house, but is not now to be found. The mass of sixty-two pounds weight has, for a short time past, been in the cabinet of natural history of I. A. Lapham, who succeeded in purchasing it.

The place where these meteorites were found, and its environs for a mile in circumference, form a hilly tract quite thickly covered by forest trees. The soil of this hilly district is a calcareous or argillaceous loam. Everywhere in the region are to be found fragmentary angular stones, often several feet in diameter, and also round and smooth ones, all of the oldest formation, which come from the so-called azoic rocks in the north of Wisconsin, and which are interspersed in the quaternary diluvium. This last forms a calcareous belt, thirty-six miles wide, along the shore of Lake Michigan to Green Bay, and is regarded as belonging to the Niagara and Clinton limestone formation.

These drift rocks (*Trümmergesteine*) often cause the cultivator great labor in reclaiming the land. It is customary to see large pyramids of stones heaped up in the fields, which the farmer has dragged together, with no little trouble, before he can till the soil. This is the case at Korb's farm to a very extraordinary degree. To the quartzose and granitic rocks strewed over this region, at an earlier time, and lying uncovered or close under the soil, it is probably to be ascribed the fact that the masses of meteoric iron which have been found had not to be withdrawn through any very deep excavations of the ground.

As Korb, and probably many others of the vicinage, had been led by the finding of these iron meteorites to conjecture the existence of rich treasures of iron ore within the earth, I sought the more strenuously to remove the disbelief in the cosmical origin of the bodies in question, especially as that origin had not at the time received the incontestable confirmation of chemical analysis.

Close to Korb's farm lies another on which is found, in the midst of a wood, a small and very deep pond in the moor land. Near to it is a ferruginous spring. On closer observation I found that this was nothing more than water flowing from the moors, and soon becoming stagnant through an overgrowth of decaying plants—showing a slight impregnation of iron—less even than much of the water drunk at Milwaukee. Only a few hundred steps from this, also in the forest, is a rather large and very deep pond, surrounded by a quaking and scarcely passable bog, some four hundred feet long and two hundred wide. The pond is called Burns's Lake. The whole scenery makes a dreary and uncomfortable impression on the mind. I have generally failed to find hereabouts minerals containing iron, though Iron Ridge stretches from Dodge County almost to the borders of Washington County.

According to Dr. G. Bode's report, submitted to the Wisconsin Society of Natural History, he has taken the samples for the careful chemical analysis which he has executed from the piece weighing sixteen pounds. This piece is externally covered with a brown, almost polished coat of oxide of iron, imparting but slight coloration; within, it is nearly of the whiteness of silver; it is very soft, but of great toughness. The so-called Widmannstäten figures, characteristic of meteoric iron, admit of being produced with great distinctness.

The specific weight of the mass amounts to 7.3272. One hundred parts contain, of iron, 89.22 per cent.; of nickle, 10.79 per cent.; of phosphorus, 0.69 per cent., and a trace of cobalt.

The composition of all meteoric iron masses, thus far examined, is very similar. Of nine different analyses, known to him, Dr. Bode states

the average contents in nickle at 10.30 per cent. The relative quantity of phosphorus is, in nearly all, higher than the above. On the other hand, most of the iron-meteorites contain traces of other substances mentioned before.

From the absence of other constituents, the meteoric iron discovered in Wisconsin is the purest which has been hitherto found; it is distinguished for its beauty, and only one other meteoric iron mass now known shares in an equal degree the characteristic of its species.

REMARKABLE FORMS OF HAILSTONES RECENTLY OBSERVED IN GEORGIA.

[Extract from a letter from Staatsrath Abich to Chevalier W. von Haidinger. From the Journal of the Austrian Meteorological Society, vol. iv, p. 417.]

I take this opportunity of giving you a preliminary notice of two hail-storms, of both of which I was fortunate enough to be a witness. The phenomena were of so unusual a character that they are well worthy of a full and precise account.

They took place within fourteen days of each other; the first on the 27th May last, at 3 p. m., the second on the 9th June, at 6 p. m. The localities were not far asunder, being both in the neighborhood of Tiflis, near Beloi Kliutsch. The morphological characters of the hailstones, which were very large, as much as sixty or seventy millimetres (2½ inches) in diameter, were as remarkable as they were dissimilar. On the first occasion they were oblate spheroids, resembling Mandarin oranges, while their structure seemed almost organic. On the second there was a fall of actual ice crystals, an occurrence which has never before been noticed, at least as far as I could discover from the literature within my reach. The stones were not mere lumps, exhibiting indistinct crystalline forms, but spheroidal bodies of definite crystalline structure, overgrown along the plane of the major axis by a series of clear crystals exhibiting various combinations belonging to the hexagonal system. The commonest forms were those which occur in calcite and specular iron. Of the former type, by far the most abundant were combinations of the scalenohedron, with rhombohedral faces; crystals of fifteen to twenty millimetres (¾ inch) in height, and corresponding thickness, prettily grouped with combinations of the prism and obtuse rhombohedra. The terminal plane was also occasionally noticeable. Some which fell at the beginning of the storm were flat, tabular, crystalline masses, thirty to forty millimetres (1½ inch) in diameter, resembling the so-called "eisen-rose," which occurs at St. Gotthardt.

The stones, when picked up quite fresh, showed sharp edges, with faces which were for the most part slightly curved like those of diamond; however, those which I took to belong to the scalenohedron were perfectly plane.

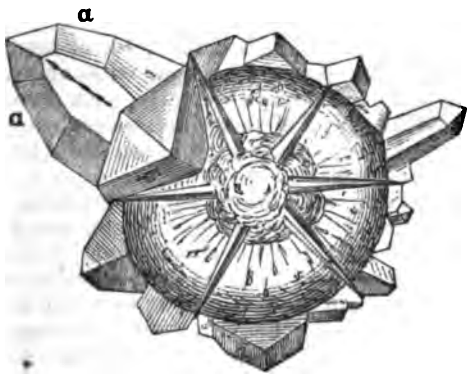
I was in the open air when each of the storms began, and was able to gain shelter before I received any injury. This was fortunate, for the damage done, even to large trees, was very serious.

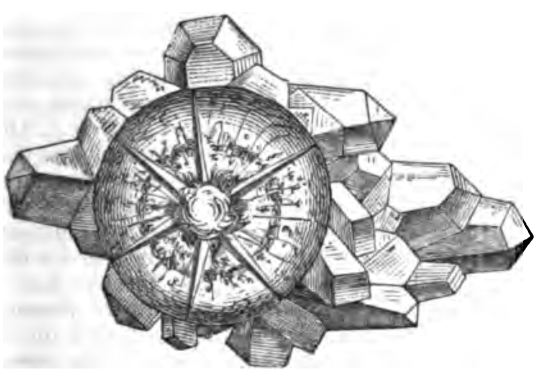
I reached home in a quarter of an hour, and found a pail full of the largest stones, which had been collected as soon as the first fright had passed over. My house was not much damaged. I sat down at once and drew ten of these remarkable forms, which had scarcely undergone any alteration.

I have often thought over our conversations about hail, and I see that if I now applied all the theories which have ever been broached to the facts which have come under my own notice, not a single one of them will give me any light toward their explanation. I would ask how such a regular growth of crystalline masses, reminding us in their character

of the drusy crystals of calcite from Andreasberg, can be reconciled with the violent atmospheric commotion which we suppose to accompany the formation of hail. We say *in naturâ nihil fit per saltus*, and I believe it. The growing crystalline mass must have been suspended for a long time in a very cold stratum of aqueous vapor before it reached the earth.

[The two subjoined cuts are copied as closely as possible from the original drawings.]





Actual representations (of the natural size) of two of the hailstones which fell in Georgia on the 9th June, 1869, drawn at the time by Staatsrath Abich.

I would only add, by way of a hint, to explain what cannot be shown by such imperfect drawings, that where the flat spheroidal forms, resembling specular iron, in the center of the drawing, exhibit shading, the crystals were not always opaque. The ring surrounding the nucleus had a milky appearance, owing to small air bubbles, as had the nucleus itself in most instances. Many of them, however, had a clear nucleus. This could easily be seen next morning, when the stones had all melted down to cakes of about an inch in diameter, occasionally taking the shape of a regular hexagon. The milky ring round the central point was clearly distinguishable as a sort of fibrous web composed of the finest air cavities traversed by threadlike pores. In some cases there was no ring, and the nucleus was semi-opaque.

The shading round the border of the large circle is only intended to mark the smooth spheroidal form of the central mass. The actual crystals were attached parasitically to its edge, or else inserted in a sort of socket, as I found when the stones thawed down. (See *a*, Fig. 1.)

All the stones contained fine air pores, pear-shaped or worm-like, running from the center to the circumference. The drawings are as near as possible natural size.

ERUPTION OF THE VOLCANO OF COLIMA IN JUNE, 1869.

COMMUNICATED BY DR. CHARLES SARTORIUS.

To the northwest of the town of Colima rise, above lower mountains, two lofty volcanic peaks, the more easterly, capped with snow, being 3,790 metres (12,434 feet) in height, the more westerly, with a conspicuous crater, 3,580 metres, (11,745 feet.) The latter had an eruption in the year 1818, but had since remained in repose, though thin clouds of smoke often ascended from its summit.

On the 12th June, 1869, a dense smoke issued from the crater and at night a bright light was visible at its mouth; detonations like the discharge of distant artillery were heard, but no concussion of the earth took place. On the 13th there was observed from the hacienda (farm) of San Marcos, four leagues distant from the volcano, on its northeast side, at the foot of the steep cone, a glowing heaving (*Anschwellung*) of the surface, which continued to increase, and displayed intensely luminous clefts, from which were ejected smoke and red-hot stones, extending in the direction of the snowy peak above mentioned.

The civil engineer, Ricardo Orosco, ascended the volcano on the 15th of June, accompanied by two servants and a guide. At 6 o'clock in the morning he left San Marco's, and reached at 12 o'clock a plain at the foot of the steep cone, where he left the horses. A heavy storm was prevailing, the temperature of the air being 10° Réaumur, (55° F.) On a second small plain upon the northeast side of the mountain was the new upheaval, which ascended to the scarp of the cone and stretched in the direction of the snowy peak, the latter being 4,500 metres (2¾ miles) distant. The upheaval in question seemed to be some 35 metres (114 feet) high and 230 metres (754 feet) broad, forming a flattened arch. The appearance was that of a wild mass of volcanic, red-hot rocks heaped one upon another and constantly in motion, not unlike freshly burnt lime when sprinkled with water. The rocks which rolled down were, on cooling, of a gray color. A piece broken off rang like glass and was vitreous and porous. In the middle of the upheaved mass the movement was strongest; there large clefts and intense light were displayed, while engulfed stones, which were swallowed up in great masses, were followed by a noise as of violent wind and by clouds of smoke, sometimes blue, sometimes yellow. The temperature of the air in the vicinity was 42° R., (126° F.) The stones in the midst of the heaving mass seemed to be softened, though not melted, and no flow of lava took place. Orosco ascended the cone in order to observe the phenomenon from above. This cone is very steep, and consists of sand and volcanic rubble. The temperature on the summit, which was reached at 2 o'clock p. m., was found to be 4° R., (41° F.) From hence the whole of the new upheaval could be surveyed. In the middle of it the most vehement movement was in progress, attended by the constant upheaving and descent of rocky masses, fire, and blue and yellow columns of smoke.

The upper (ancient) crater has a diameter of 150 metres, (492 feet,)

descends in a cone-like form, and shows around its circumference many fissures and rifts. From the center and walls arose a dense sulphurous vapor. The gases from the new theater of eruption had a smell like that of burning stone-coal.

The descent was very toilsome on account of the rolling stones. At 3.30 p. m. the horses were reached, and at 9.30 the hacienda of San Marcos, where many were waiting to learn the result of the expedition. The report of Orosco was, that the district was threatened with no danger, as no lava was issuing, and the fissures being open gave no reason to fear any explosion from the tension of confined vapors. Later explorers of the volcano found a fissure from the new upheaval to the upper peak, one to three feet wide and about three feet in depth, but neither heat nor vapor issuing from it. The latest reports inform us that the same phenomena in general continue to present themselves, but that such volumes of fetid gases issue from the fissure, that the inhabitants of the district were forced to leave their abodes. Cows and sheep were killed thereby, so that it was found necessary to drive away the herds from the neighborhood of the volcano.

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